Telephone Systems

EB-552A-50 INSTRUCTOR'S GUIDE 595-5882-02

Telephone Systems, Instructor's Guide
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CONTENTS

Introduction 4
Course Prerequisites 4
Course Objectives 5
Course Outline 6

Lesson Plan 9
Sample Lesson Plan 9
General Lesson Plan 10

Exercise Introduction 31
Required Equipment 32
ETB-552A Exercise Module Description 32

Exercise Answers 34
Exercise 1: The Local Loop 35
Exercise 2: System Signal Levels 38
Exercise 3: Switching and Dial-Up 43
Exercise 4: Tone Detecting and Decoding 50
Exercise 5: Transmission Lines and Signals 53
Exercise 6: Two-Wire/Four-Wire Transmission 58
Exercise 7: Noise and Transmission Impairments 65

Self-Test Review Answers 71
Chapter 1 71
Chapter 2 73
Chapter 3 74
Chapter 4 78
Chapter 5 79
Chapter 6 82
Chapter 7 85
Chapter 8 86

Section Examinations and Answers 89
Section 1 Examination 90
Section 1 Examination Answers 94
Section 2 Examination 97
Section 2 Examination Answers 100
Section 3 Examination 102
Section 3 Examination Answers 105

Final Examination 107

Final Examination Answers 117

INTRODUCTION

This Instructor's Guide accompanies the Heathkit Educational Systems course Telephone Systems. The students will be reading the Textbook and performing the exercises in the Laboratory Workbook; the Instructor's Guide gives the answers to all the questions within these two books. This instructor's guide was developed to go along with the EB-552A Textbook, part number 595-5880 and subsequent versions, and the EB-551A-70 Laboratory Workbook, part number 595-5881.

To the greatest extent possible, this guide does not duplicate material found in the Textbook or Workbook. For example, answers to pertinent exercise procedure questions are presented in this guide in the context of the original question; however, those sections of the exercise which do not require an answer are not reproduced here.

This Instructor's Guide provides guidelines and information for all phases of the course. First, it lists the course prerequisites, objectives, and outline. Second, it provides a sample lesson plan, outlining the recommended sequencing for text and exercise completion. Third, it provides details and answers for the Workbook exercises. Fourth, it provides the answers to the Self-Test Reviews within the Textbook. Finally, this guide provides Chapter and Final examinations (and their answers), which allow you to properly test your students.

COURSE PREREQUISITES

This course has been written with the assumption that the student has already completed basic electronics training. The student should already understand basic circuitry, oscilloscope and multimeter operation, and calculations involving DC and AC circuits. Telephone Systems is designed to follow basic electronics, and the fourth in the Heathkit Educational Systems' series of courses on Telecommunications.

COURSE OBJECTIVES

Upon completion of this course, the student should be able to:

- Name and explain the function of each part of a telset.
- Explain, in detail, the equipment used to complete a telephone call from a local subscriber to a distant, long-haul subscriber.
- Explain and calculate the electrical properties of transmission lines in units of R, L, and C.
- Describe the difference between key, PBX, and Centrex telephone systems.
- Describe the operation of a modern cellular telephone.

COURSE OUTLINE

Introduction

Section 1—Telephone Fundamentals

Chapter 1 - Basic Telephone Service
- Introduction
- Objectives
- Overview of the Basic Telephone Service
- The Local Loop
- Signals and Signaling
- Sequence of Operation
  - Completing a Local Call
- Calling Beyond the Local Central Office
- Summary
- Self-Test Review

Chapter 2 - Telephone Equipment
- Introduction
- Objectives
- The Telephone Set
- The Network
  - The Transformer Network
  - The IC Network
- The Dial
  - Tone Dialing
- Summary
- Self-Test Review

Chapter 3 – Facilities,Telset, and Central Office Circuitry
- Introduction
- Objectives
- Connection Through Facilities
  - Loading Telephone Circuits
  - Station Wiring
- The Telephone Set
  - Electronic Telephones
  - Cordless Telephones
- The Central Office
  - Central Office Operation and Control Office Communication
- Summary
- Self-Test Review

Section 2—Transmission Signals And Circuits

Chapter 4 – Generating and Detecting Signals
- Introduction
- Objectives
- Creating Signals
  - Oscillators
  - Relaxation Oscillators
  - Multivibrators
- Detecting Signals
  - Detecting Frequency
  - Detecting Power Levels
  - Time Division
- Summary
- Self-Test Review

Chapter 5 – Transmission Lines
- Introduction
- Objectives
- Electrical Properties of Lines and Circuits
  - Resistance
  - Impedance
  - Capacitance
- Impedance and Phase
  - Phase Factors
- Coaxial Cables
- Summary
- Self-Test Review

Chapter 6 – Conditioning of Lines and Circuits
- Introduction
- Objectives
- Signal Losses and Conditioning
  - Line Loading and Conditioning
  - Line Compensation
- Conditioning Standards
  - C-Type Compensation
  - D-Type Compensation
  - Specifications
- Measurements
- Summary
- Self-Test Review

Section 3—Advanced Telephone Systems

Chapter 7 – Business Telephone Systems
- Introduction
- Objectives
- Key Telephone System
- Private Branch Exchange (PBX)
  - Digital PBXs
  - Wireless PBX
- Central Office Exchange (Centrex)
- Summary
- Self-Test Review

Chapter 8 – Cellular Telephones
- Introduction
- Objectives
- History of Mobile Telephones
- How Cellular Telephones Work
  - Registration and Tracking
  - Placing a Phone Call
  - Roaming
- The Cellular Phone
- The Cellular Base Station
- Cellular Problems
- Personal Communications Service (PCS)
  - Description
  - Technical Aspects
  - Advantages of PCS
  - Disadvantages of PCS
  - Future Outlook
  - Recent FCC Action
- Summary
- Self-Test Review

LESSON PLAN

The general lesson plan is divided into two sections, corresponding to the four sections in the Textbook. Each section is divided into segments, corresponding to the text prior to each Self-Test Review. It is up to you to personalize your lesson plan. Ample space is provided for detailed notes.

Each exercise is listed under "Laboratory Activity" in the General Lesson Plan, immediately following the Section in which the topic is covered. It is up to you to decide on the best time to perform each exercise.

A Sample Lesson Plan follows, indicating how much material could be taught each week for a 6-week course. This sample is by no means a hard and fast rule, only a guideline.

SAMPLE LESSON PLAN

	Section	Chapter	Subject
Week One:	1	1	Basic Telephone Service
		L	Lab Exercise 1
	1	2	Telephone Equipment
		L	Lab Exercise 2
Week Two:	1	3	Facilities, Telset, and Central Office Circuitry
		L	Lab Exercise 3
Week Three:	1	E	Section Review and Exam
	2	4	Generating and Detecting Signals (Part 1)
		L	Lab Exercise 4
		L	Lab Exercise 5
Week Four:	2	4	Generating and Detecting Signals (Part 2)
	2	5	Transmission Lines
		L	Lab Exercise 6

	Section	Chapter	Subject
Week Five:	2	6	Conditioning of Lines and Circuits
		L	Lab Exercise 7
	2	E	Section Review and Exam
Week Six:	3	7	Business Telephone Systems
	3	8	Cellular Telephones
	3	E	Section Review and Exam
			Course Review
			Lab Equipment Turn-In
			Final Examination

GENERAL LESSON PLAN

SECTION 1 TELEPHONE FUNDAMENTALS
Chapter 1 — Basic Telephone Service

[Time (hours):_____]

Objectives Covered:

1. Define the distinctive vocabulary terms used in telephone practice, and relate them to electrical principles and terminology.

2. Identify each of the signals and messages used to operate local telephone services; including those signals that originate in the telset, and those that originate at the central office.

3. List the sequence of operations necessary to complete a local telephone call within a single zone of service.

4. Identify the structure and service areas of the Public Telephone Network's digit dialing numbering plan.

5. Specify the interconnect and switching hierarchy of the local exchanges and the long-haul network.

Topics Covered:

- Introduce the structure of the Public Telephone Network, and describe the line side and truck side circuits emanating from the central office; then, describe the switching hierarchy through trunk circuits and the long-haul network.

- Describe the operation of the local loop connections from the central office to the single line telset, and identify each of the electrical components within this circuit.

- Specify all of the power and signals provided by the central office to the single-line telset, and the signals returned to the central office from the telset, that assures the operation of the telephone system.

- Identify and describe each of the steps required for completing a local telephone call.

- Describe the hierarchy of digits used in dialing a 10-digit phone number, beginning with the area code; then, relate the switching hierarchy (local CO, tandem switch, etc.) to each of the numbers dialed.

Assignment:

Self-Test Review

INSTRUCTOR NOTES

SECTION 1 TELEPHONE FUNDAMENTALS
Chapter 2—Telephone Equipment

[Time (hours):_____]

Objectives Covered:

1. Identify the name, function, and operation of each of the functional parts of a telset, central office, and local facilities.

2. Specify the operating voltages, currents, and frequencies of the central office and telset required for proper operation of local telephone services.

3. Specify the wiring connections between the local central office and telset for proper operation of the telephone services.

4. Describe, in detail, the operation of a transformer and electronic hybrid voice network, as used in the telset.

5. Specify the time standards for dial pulses used to access locations in the central office switch and complete a telephone circuit.

6. Specify the frequency and time standards for dial tones Dual Tone Multi Frequency (DTMF) to access locations in the central office switch and complete a telephone circuit.

7. Describe the detailed operation and function of each component in the electronic single-line telset.

8. Describe the functional operation of each section of the electronic single-line telset.

Topics Covered:

- Identify and describe each of the elements within the standard single-line telset; including the voice network, dial, ringer, transmitter, and receiver.

- Describe, in detail, the operation of the hybrid voice network, using both transformer and IC configurations.

- Describe, in detail, the dial and dial network of a rotary dial telephone; and detail the dial-pulse timing sequence.

- Describe the operation and specifications of dial frequencies in the DTMF tone dialing configurations; including the two-tone frequencies available at each digit of the dial pad, and the techniques used to generate the dual-tone frequencies.

Assignment:

Self-Test Review

INSTRUCTOR NOTES

SECTION 1 TELEPHONE FUNDAMENTALS
Chapter 3—Facilities, Telset, and Central Office Circuitry
[Time (hours):_____]

Objectives Covered:

1. Identify the name, function, and operation of each of the functional parts of a telset, central office, and local facilities.

2. Specify the operating voltages, currents, and frequencies of the central office and telset required for proper operation of local telephone services.

3. Specify the wiring connections between the local central office and telset for proper operation of the telephone services.

4. Describe the proper connection of extension telephones off of a single wire-pair, and calculate the loading affected by their operation.

5. Calculate the relationship between loop resistance, and the operating voltage and current available to a single-line telset.

6. Describe the detailed operation and function of each component in the electronic single-line telset.

7. Describe the functional operation of each section of the electronic single-line telset.

8. List, and describe the purposes of each of the central office functions that are activated by the loop relay.

9. Describe loop-start and ground-start operation of local telephone services.

10. Identify and describe the effects of signal conditioning along telephone lines and circuits.

11. Describe the character of lineside and trunkside wiring and circuits used from one telset, through a central office, and the long haul network.

12. Describe the detailed operation and functions of a 2/4-wire converter.

Topics Covered:

- Identify and describe the interconnection of single-line telephones through facilities from the central office, through facilities to the telset terminal equipment.

- Describe and show the techniques of calculating "talk battery" DC voltage drops along the local loop that add resistance; then, account for the effects (include ringer circuit loading) of extension telsets operated in parallel along the same local loop circuit.

- Describe, in detail, the schematic and wiring diagrams of a conventional telset to identify each of the components within the equipment; then, describe the general diagram of the electronic telset, and identify each of the IC blocks within that equipment.

- Specify the operating characteristics of the telset in the local loop.

- Describe the operation of the central office and the signals and power it provides to the line side (local loops) of its operation; then, proceed to describe the trunk side operation of the CO, including the use of 4-wire circuits.

Assignment:

Self-Test Review

Section One Laboratory Activity:

- Exercise 1: The Local Loop
- Exercise 2: System Signal Levels
- Exercise 3: Switching and Dial-Up
- Exercise 4: Tone Detecting and Decoding

Section One Examination

Give a comprehensive review of the exam upon its completion.

INSTRUCTOR NOTES

SECTION 2 TRANSMISSION SIGNALS AND CIRCUITS
Chapter 4—Generating and Detecting Signals

[Time (hours):_____]

Objectives Covered:

1. Identify the distinctions used to classify analog versus digital techniques used in creating electrical signals.

2. Describe the general operating characteristics of oscillator circuits used to generate sine wave signals.

3. Describe the general operating characteristics of relaxation oscillator circuits used to generate ramp and sawtooth waveform signals.

4. Describe the general operating characteristics of multivibrator circuits used to generate triangle and squarewave signals.

5. Describe the general operating characteristics of digital IC frequency generator circuits used to generate triangle and squarewave signals at frequencies divided down from a high-frequency clock oscillator.

6. Identify and categorize the dominant analog and digital techniques used for electrical signal detection and driving common annunciators.

7. Classify the characteristics of signals to which detector circuits are applied; including, the presence of signals, frequency and phase discrimination, triggering from power levels, and triggering from time periods.

Topics Covered:

- Describe the general feedback and gain requirements for creating an oscillator from a linear amplifying device; then, identify how popular oscillator circuits achieve this function.

- Describe how non-linear switching and digital circuits are configured using RC timing components to function as oscillators and multivibrators.

- Review the digital circuitry of the IC DTMF tone generator, and describe how each of the blocks of the device function to create the 16 DTMF tones.

- Introduce the functions of circuits used to detect DTMF and other signaling signals within the central office switch; then, detail the operation of the phase-locked loop as a tone decoder.

- Describe the use of signal comparators to detect signal or DC power levels, and identify how the CO processes these signals in its operation.

- Describe how IC timers function with RC components to detect time-based signals, and how the CO processes these signals in its operation.

Assignment:

Self-Test Review

INSTRUCTOR NOTES

SECTION 2 TRANSMISSION SIGNALS AND CIRCUITS
Chapter 5 — Transmission Lines

[Time (hours):_____]

Objectives Covered:

1. Specify and calculate the electrical properties of transmission lines, in units of R, L, and C, from their geometry and insulation materials.

2. Specify and calculate the effects of electrical properties upon a transmission line's characteristic impedance.

3. Determine the effects of line impedance upon the transfer of signal power and frequency response characteristics of transmission lines.

4. Apply the concepts of phase shift due to the LC properties of transmission lines, to the velocity of signals moving along the lines.

5. Describe and calculate the velocity factor of signals moving along transmission lines.

6. Describe the non-linearities of R, L, and the velocity of signals in transmission lines due to skin effect.

7. Describe the structure and advantages of coaxial cable, and calculate its electrical properties from specifications of its geometry and insulation material.

Topics Covered:

- Describe the transmission line in terms of its resistive properties, and demonstrate by example, the line resistance as a function of distance and conductor diameter; then, identify the popular wire gauge diameters and resistance of copper lines used in telephone circuits.

- Describe the transmission line in terms of its inductive and capacitive properties, and demonstrate by example, these properties as a function of distance, conductor diameter, conductor spacing, and dielectric insulation.

- Demonstrate the techniques of calculating the resistance, inductance, and capacitance of the two-wire transmission line based upon its geometry and the dielectric characteristics of its insulation.

- Describe the transmission line as an electrical network in terms of its impedance and phase-shift properties; use the concepts of distributed networks.

- Compare two-wire lines to coaxial cables; include distributed series resistance, inductance, and capacitance, and the impedance and phase characteristics.

Assignment:

Self-Test Review

INSTRUCTOR NOTES

SECTION 2 TRANSMISSION SIGNALS AND CIRCUITS
Chapter 6 — Conditioning of Lines and Circuits

[Time (hours):_____]

Objectives Covered:

1. Define the techniques used to condition transmission lines to pass signals with uniform frequency response and minimum loss.

2. Describe and calculate the effects of shunt capacitance upon the frequency response and signal losses within transmission lines.

3. Describe the use and effects of loading coils placed along transmission lines to cancel the effects of capacitance upon a line's frequency response.

4. Describe the use and effects of amplifiers placed within transmission circuits to compensate for a line's frequency response and attenuation characteristics.

5. Identify the major operating standards for transmission lines and circuits used in voice-channel telecommunication practice.

6. Identify the specifications of C-type and D-type line conditioning, and the operating standards they define.

7. Define the units of measurement used by telco in defining critical power levels of signals and noise within transmission lines and circuits.

8. Identify and describe the fundamental measurements and setups used to evaluate the performance of transmission lines and circuits.

Topics Covered:

- Describe the need for line conditioning to equalize the frequency response of transmission circuits; then, define the electrical properties which compensate for slope and high-frequency line losses.

- Demonstrate the techniques of calculating line losses by treating the transmission line as a simple electrical RLC network.

- Introduce the practice of line compensation and equalization using loading coils applied at specified distances along transmission circuits; then, describe the practice of electronic equalization by adjusting the frequency tilt characteristics of amplifiers placed within four-wire circuits.

- Detail the C-type and D-type conditioning standard specifications for telephone practice; then, define the terms used to specify standard and actual signal levels in telephone practice, e.g., TLP, dBrnC, etc.

- Describe the standard measurements applied to telephone practice, and the properties to be measured; including message power and frequency response, C-message noise, T.H.D. and IMD, and phase distortion, as measured using P/AR techniques.

Assignment:

Self-Test Review

Section Two Laboratory Activity:

- Exercise 5: Transmission Lines and Signals
- Exercise 6: Two-Wire/Four-Wire Transmission
- Exercise 7: Noise and Transmission Impairments

Section Two Examination

Give a comprehensive review of the exam upon its completion.

INSTRUCTOR NOTES

SECTION 3 ADVANCED TELEPHONE SYSTEMS
Chapter 7 — Business Telephone Systems

[Time (hours):_____]

Objectives Covered:

1. Describe the differences between key, PBX, and Centrex telephone systems.

2. List the steps required to make an outside call with both key and PBX systems.

3. Describe the main blocks that make up a key service unit.

4. Decribe the main blocks that make up a PBX system.

5. Explain the purpose of a CODEC.

6. Explain how a wireless PBX system works.

Topics Covered:

- Describe the components and operating characteristics of a key telephone system.

- Describe the components and operating characteristics of a PBX telephone system.

- Describe a typical wireless PBX in a business environment.

- Describe the components and operating characteristics of a Centrex telephone system.

Assignment:

Self-Test Review

INSTRUCTOR NOTES

SECTION 3 ADVANCED TELEPHONE SYSTEMS
Chapter 8 — Cellular Telephone

[Time (hours):_____]

Objectives Covered:

1. Describe the basic differences between older mobile telephones and today's cellular telephones.

2. Describe the concept of a cellular system and the makeup of a call.

3. Explain how handoffs amd roaming work.

4. List the basic circuits of a cellular phone and the purpose of each.

5. List the basic circuits of a cell site and the purpose of each.

6. Describe the Personal Communications Service (PCS).

7. Explain the meaning of the terms "dropout" and "dead zones."

Topics Covered:

- Describe how mobile telephone has changed from its inception in 1946 to the present cellular system.

- Identify the frequency ranges used by cellular phones and how the cellular systems work.

- Describe how calls are handled through a group of cells and one or more systems.

- Explain the basic circuits of a cellular telephone and cellular base station (cell site).

- Describe some problems with cellular telephones.

- Describe the features available with PCS phones and how they work.

- Explain the advantages and disadvantages of PCS.

- Explain what the future should bring for PCS phones.

Assignment:

Self-Test Review

Section Three Examination

Give a comprehensive review of the exam upon its completion.

Comprehensive Review of Course

Use Course Outline as a guide for a comprehensive review of all course material. Review the Section Examinations and Self-Test Reviews.

Comprehensive Final Examination

Optional review of exam upon its completion and scoring.

INSTRUCTOR NOTES

EXERCISE INTRODUCTION

The Laboratory Exercises are intended to teach **understanding**, the understanding of what, why, and how. Specifically, the goals of the activities intend to teach the following:

1. The application of test equipment and procedures to measure telecommunication signals and circuits.

2. The interpretation of measured data to determine the functions and operation of telecommunication circuits.

3. The analysis of measured data to better understand the theoretical basis of communication signals, circuits, and systems.

The Laboratory Workbook is designed to be used in a classroom in an environment with strong instructor support. The application of test equipment and procedures must be demonstrated to students prior to their lab work. Even with a thorough introductory demonstration, the students will still require assistance while managing the measurements and procedures.

To assure instructor support, there are check-off boxes for the instructor's initial at critical points in the exercise procedures. Students should demonstrate both their understanding of the measurement techniques, and the implications of the measured data, to obtain an approval mark from the instructor. There should also be some discourse (chit-chat) between the instructor and student at these points to elaborate the learning process. Always keep in mind the goal of **understanding** on the part of the student. To be a success in a technical career field, students need to know what they are measuring, why they are measuring it, and how to make the measurement. The instructor can assure better understanding through discussions and individual demonstrations with students during the lab procedures.

The ideal weekly lab session may be three to four hours in duration; with one to two hours scheduled for instructor demonstration, and at least two hours scheduled for student laboratory activity. Since all students don't work at the same pace, however, it is likely that additional open lab time may be required for some students to complete the assigned exercises. There are a variety of alternative patterns of structure for the lab, but there should always be time scheduled for the instructor demonstration.

REQUIRED EQUIPMENT

The EB-552A course has been designed around the Heathkit ETW-5000 Telecommunications Trainer with ETW-3567 Backpack and ETB-552A Exercise Module. Students can complete all of the exercises in the Laboratory Manual using only one additional piece of test equipment, an oscilloscope.

The ETW-5000/ETW-3567 contain the functions of many separate interconnected pieces of test equipment which makes lab work very time-efficient. The structure of the ETW-5000/ETW-3567 also emphasizes the systems test set concept of test equipment, typical of what is used in the telecommunications industry. The ETW-5000 includes a 5-waveform function generator that can be switched to modulate a 5-mode carrier generator, a frequency counter, wideband amplifier, attenuator, and power meter. The ETW-3567 includes a digital multimeter and interface access to a slide-in Exercise Module. Both units include power supplies and loudspeakers.

The specific requirements for an oscilloscope to use with this lab course include dual-trace operation, with X-Y capability, 20 MHz vertical bandwidth, and 5 mV/div vertical sensitivity. Two ×1 probes with hook-on and BNC connectors are also required.

ETB-552A EXERCISE MODULE DESCRIPTION

The ETB-552A Exercise Module slides into the rails and interface connectors of the ETW-3567 backpack for operation with the test system in performing the Laboratory Exercises.

The ETB-552A Module includes the circuitry to simulate the functions of an operational telephone central office, as well as, transmission and components circuits. Two electronic telephone sets connect to this board to simulate a complete operational telephone communications system. The components on this board are also used in the study of the electrical fundamentals that are a foundation of telecommunications technology.

The ETB-552A Module includes the circuitry used in the study of the fundamentals of electronic communication signals and systems. These circuits comprise a line amplifier, balanced modulator, noise source, DTMF/tone decoder, dial register and display, and dual-tunable electronic filter. The filter is used to analyze the spectral distribution of harmonic and intermodulation signals, as well as, function in performing standard transmission system measurements.

To perform the exercises, the circuits are interconnected on the ETB-552A Exercise Module with wires that easily plug onto circuit board pins.

EXERCISE ANSWERS

EXERCISE 1

The Local Loop

6. (**NOTE TO THE INSTRUCTOR:** The values shown in Figure 1-2 are examples only, the values obtained by your students may differ slightly.)

MINIMUM LINE RESISTANCE

TELSET	T/R TERMINALS	R103	R106	RY101	R104
OFF-HOOK	–9V	–1V	0V	–12V	–2V
ON-HOOK	–33V	0V	0V	0V	0V
T/R SHORTED	0V	–1.5V	0V	–18V	–2.5V

Figure 1-2

9. (**NOTE TO THE INSTRUCTOR:** The values shown in Figure 1-3 are examples only, the values obtained by your students may differ slightly.)

MAXIMUM LINE RESISTANCE

TELSET	T/R TERMINALS	R103	R106	RY101	R104
OFF-HOOK	–6V	–0.5V	–16V	–4.5V	–2V
ON-HOOK	–33V	0V	0V	0V	0V
T/R SHORTED	0V	–0.6V	–20V	–5.5V	–2.1V

Figure 1-3

10. T/R terminals (Telset on-hook) ≈ **–33** VDC

11. T/R terminals (Telset disconnected) ≈ **–33** VDC

Based upon your measurements in Steps 10 and 11, can you tell the difference between a terminated connection with a telset on-hook, and an unterminated connection?

no

Assume for a moment that you are a technician in the field. If you had a pair of unmarked wires, a ground, and a voltmeter, how could you distinguish between the T and R wires?

Whichever wire is more negative when measured across ground is the R wire.

16. E_{R4} ≈ **–0.75** VDC

Loop Current ≈ **27 mA**

INSTRUCTOR NOTES

EXERCISE 2

System Signal Levels

6. Voice level (line resistance max) ≈ 1 Vp–p

   NOTE TO THE INSTRUCTOR: The values for Step 7 are obtained using the 1 volt p–p measurement in Step 6. The values obtained by your students depend upon their p–p voltage measurement in Step 6. This also applies in Step 8, where we used a 2 volt p–p measurement to perform the calculations.

7. Voice level (line resistance max) ≈ **0.3535** Vrms

   Voice level (line resistance max) ≈ **0.208** mW

   Voice level (line resistance max) ≈ **–6.81** dBm

8. Voice level (line resistance min) ≈ **2** Vp–p

   Voice level (line resistance min) ≈ **0.707** Vrms

   Voice level (line resistance min) ≈ **0.833** mW

   Voice level (line resistance min) ≈ **–0.79** dBm

   How much additional dBm loss occurs when line resistance is maximum?

   Approximately –6.02 dBm

12. Is the tone in Telset #2 higher or lower than for Telset #1?

    lower

14. Output (highest level) ≈ **–25** dBm

    What is the dB loss through the system?

    dB loss ≈ **25** dB

16. Output (lowest level) ≈ **–40** dBm

What is the dB loss through the system?

dB loss ≈ **40** dB

17. **NOTE TO THE INSTRUCTOR:**The values shown in Figure 2–3 are examples only, your students' values will probably be different, but the same general results should be obtained.

VOLTAGE (Vp-p)	TELSET #1	TELSET #2	VOLTAGE (Vp-p)
0.3	TP105	TP110	0.05
0.15	TP103	TP129	0.045
1.3	TP106	TP111	0.005

Figure 2-3

Are the voltage levels for each Telset #2 test point lower than the voltage levels for their corresponding Telset #1 test points?

yes

By reviewing the circuit configuration, the dB loss in the circuit is caused by which component(s)?

R101, R103, R105, R106, TR101, and TR102

19. Output (input removed) ≈ **–46** dBm

22. Difference ≈ **4** dB

23. **NOTE TO THE INSTRUCTOR:** The answer for Step 23 is a verification of Step 22 by another student.)

29. Which telset has the lower sound level?

Telset #2

30. Output (1000 Hz) ≈ **–41** dBm

31. Output (3.6 kHz) ≈ **–36** dBm

33. Does the sound level of the tone increase or decrease?

decrease

34. Does the sound level of the tone increase or decrease?

decrease

Which switch position causes the *highest* sound level?

B

Which switch position causes the *lowest* sound level?

C

35. Does the Meter provide a level indication in relation to the sound level of the Telset #2 receiver for each switch position?

yes

Why?

The Meter is set to measure the power level of the Telset #2 signal.

What other signal is affecting the level indication of the Meter?

Noise

37. Which switch position corresponds to the *highest* voltage level at TP129?

B

Which switch position corresponds to the *lowest* voltage level?

C

Do the switch positions that correspond to the highest and lowest voltage levels match the switch positions that correspond to the highest and lowest sound level, as you determined in Step 34?

yes

39. Is the voltage level higher or lower when the capacitors are connected?

higher

40. Is the power level higher or lower when the capacitors are added?

higher

41. Is the sound level higher or lower when the capacitors are added?

higher

INSTRUCTOR NOTES

EXERCISE 3

Switching and Dial –Up

9. Did the storage display clear?

yes

Which of the digit display LEDs lit?

L908 (1)

Did it remain lit?

no

10. Describe how the storage display LEDs reacted:

The storage display tried to toggle, but then cleared.

Describe how the digit display reacted:

The digit display toggled once, then cleared after approximately one second.

11. Describe how the storage display LEDs reacted:

L701 lit, then cleared immediately.

Describe how the digit display reacted:

The digit display toggled all the way to L917.

12. Describe how the storage display LEDs reacted:

The storage display toggled and cleared.

Describe how the digit display reacted:

The digit display toggled and cleared.

13. Describe how the storage display LEDs reacted:

    The storage display toggled.

    Describe how the digit display reacted:

    The digit display toggled.

14. Describe how the storage display LEDs reacted:

    The storage display toggled.

    Describe how the digit display reacted:

    The digit display toggled.

17. How did the storage display react?

    The storage display toggled and cleared.

    How did the digit display react?

    The digit display toggled, and cleared after approximately one second.

    Are these reactions consistent with the conclusions reached in the previous Discussion?

    yes

18. Did the digit display indicate the count for each digit in the phone number?

    yes

    Did the storage display indicate which digit in the phone number was being displayed by the digit display?

    yes

19. How did the storage display react?

The storage display cleared.

How did the digit display react?

The digit display cleared.

Which step in a typical phone call sequence (e.g., "request for service") does this action represent?

Disconnect.

21.

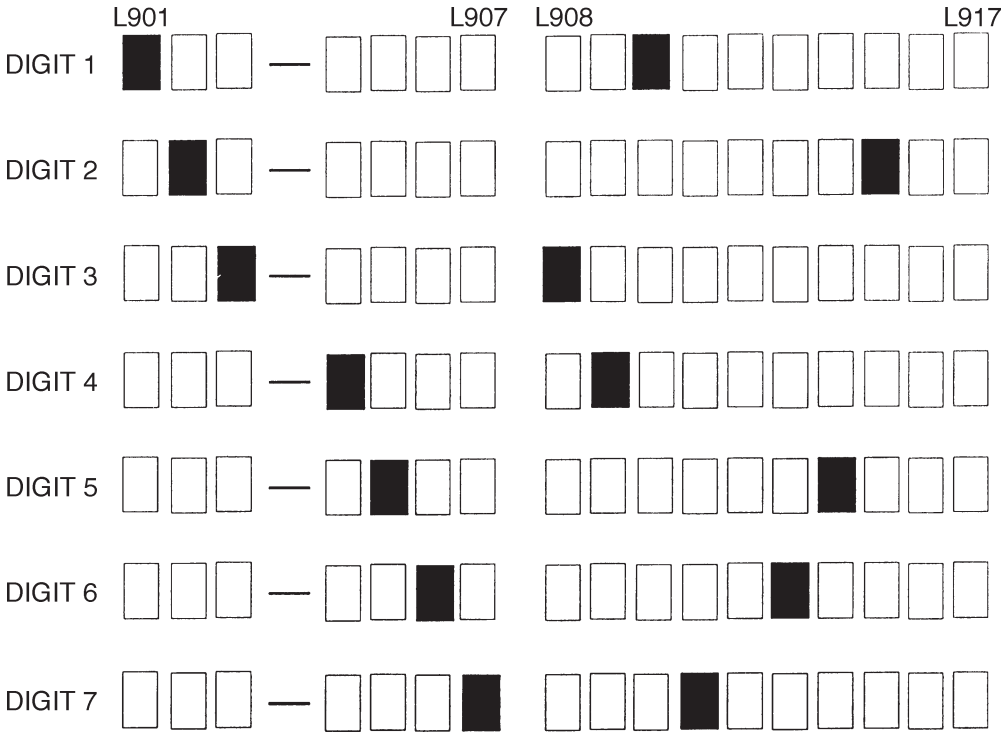

Figure 3-3

28.

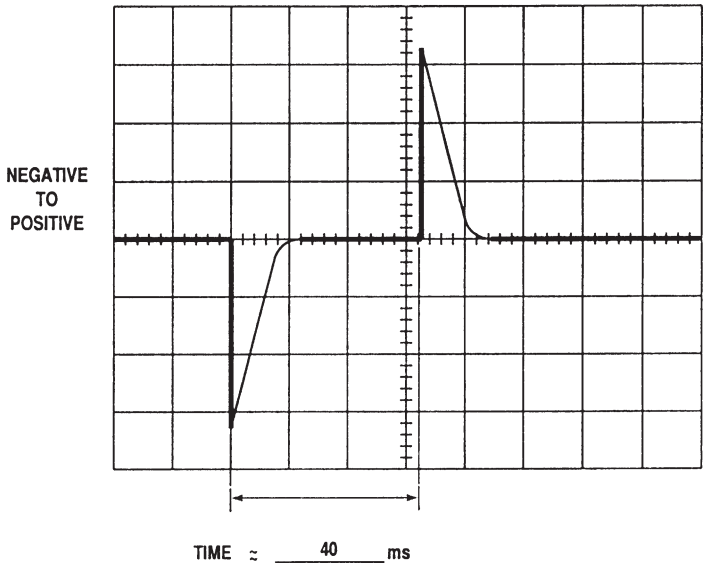

Figure 3-6A

30.

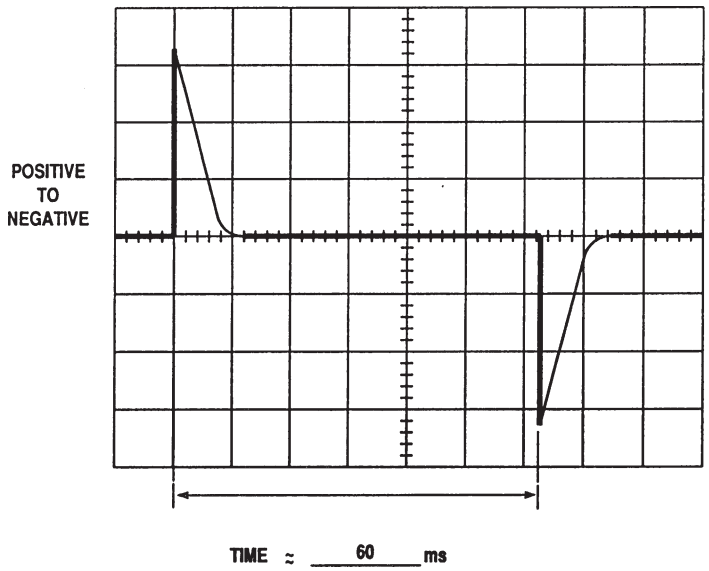

Figure 3-6B

31. Pulse period ≈ **100 ms**

35.

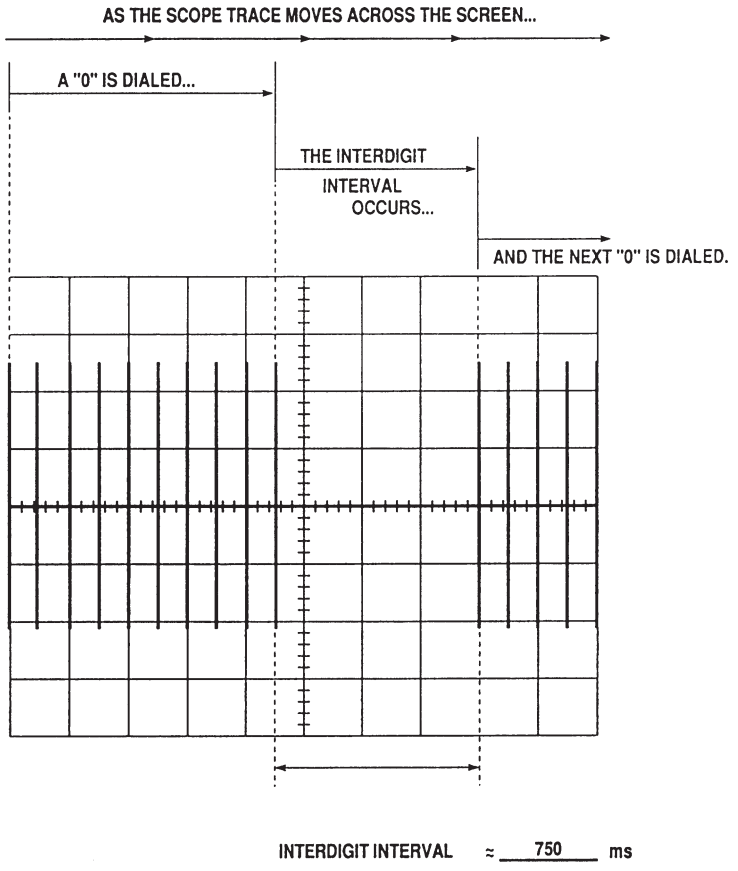

Figure 3-9

Is the value you measured within this range?

yes

38. Are the LEDs giving their proper display for a dialed number?

no

Does the digit display clear after each digit?

no

Does this interval allow the Dial Register and Display Circuit to function properly?

no

40. Are the LEDs giving their proper display for a dialed number?

yes

Does the digit display clear after each digit?

yes

Does the preset interdigit interval allow the Dial Register and Display Circuit to function properly?

yes

42. Are the LEDs giving their proper display for a dialed number?

yes

Does the digit display clear after each digit?

yes

Does the "count" of the digits within a number alter the interdigit interval?

no

48. Is the "dial tone" present?

yes

49. Is the "dial tone" disconnected after the first digit is dialed?

yes

50. Is the "dial tone" present?

yes

INSTRUCTOR NOTES

EXERCISE 4

Tone Detecting and Decoding

9. Low Frequency (R201 CW) ≈ **225** Hz

10. High Frequency (R201 CW) ≈ **255** Hz

    U202 Frequency Range (R201 fully CW) ≈ **225 to 255** Hz

11. U202 Frequency Range (R201 fully CCW) ≈ **870 to 960** Hz

13. U202 Frequency Range ≈ **2380 to 2530** Hz

15. U202 Frequency Range ≈ **940 to 1070** Hz

16.

CAPACITORS	R201	FREQUENCY RANGE	MID-RANGE
C205, C206	CW	220 - 260 Hz	240 Hz
C205, C206	CCW	845 - 930 Hz	900 Hz
C205 only	CCW	2226 - 2500 Hz	2450 Hz
C205 only	CW	835 - 975 Hz	900 Hz

Figure 4-2

CAPACITORS	R202	FREQUENCY RANGE	MID-RANGE
C207, C208	CW	445 - 515 Hz	475 Hz
C207, C208	CCW	1720 - 1920 Hz	1825 Hz
C207 only	CW	2060 - 2400 Hz	2230 Hz
C207 only	CCW	5640 - 6200 Hz	5925 Hz

Figure 4-3

24. Did the storage display toggle?

yes

Did the digit display toggle and clear?

yes

25. Did the storage display toggle?

yes

Did the digit display toggle and clear?

yes

26. Did the storage display toggle?

yes

Did the digit display toggle and clear?

yes

27. Did the storage display toggle?

yes

Did the digit display toggle and clear?

yes

32. To which row or column will the decoder be tuned?

Column 1

35. To which row or column will the decoder be tuned?

Row 3

INSTRUCTOR NOTES

EXERCISE 5

Transmission Lines and Signals

6.

TRANSMISSION CIRCUIT (BLOCK 6) SWITCH POSITIONS	FREQUENCY (Hz)					
	500	1K	1.5K	2K	2.5K	3K
SW601-B; SW602-B; SW603-1, SW603-2 DOWN	– 6	– 6	– 6	– 6	– 6	– 6
SW601-B; SW602-C; SW603-1 UP, SW603-2 DOWN	– 6	– 6	– 7	– 7	– 8	– 9
SW601-B; SW602-C; SW603-1; SW603-2 UP	– 9	– 12	– 14	– 16	– 17	– 19
SW601-A, SW602-C; SW603-1, SW603-2 UP	– 10	– 10	– 10	– 10	– 10	– 10
SW601-C; SW602-C; SW603-1, SW603-2 UP	– 8	– 7	– 7	– 6	– 6	– 6

Figure 5-2

7.

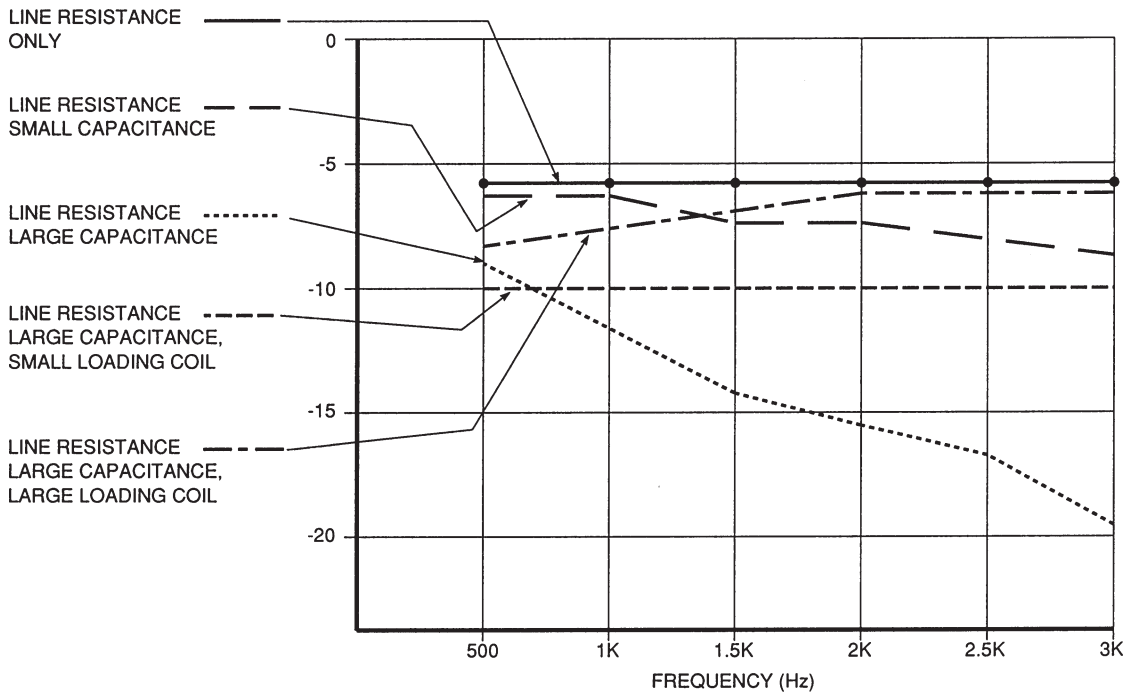

Figure 5-3

8. Describe the line conditions simulated by each set of switch positions, and how the frequency response curves you just plotted correlate to these simulated conditions:

   SW601-B, SW602-B: Line resistance only, and a small amount of signal loss.

   SW601-B, SW602-C, SW603-1 up: Line resistance and moderate amount of distributed capacitance. A small increase in signal loss.

   SW601-B, SW602-C, SW603-1 and SW603-2 up: Line resistance and large amount of distributed capacitance. A large increase in signal loss.

   SW601-A, SW602-C: Line resistance, large distributed capacitance, and moderate loading coil effect. This somewhat reduces the additional loss caused by the distributed capacitance.

   SW601-C, SW602-C: Line resistance, large distributed capacitance, and large loading coil effect. This almost completely reduces the loss caused by the distributed capacitance.

10. Resistance = **1644** Ω

    Capacitance = **0.48** µF

    Attenuation = **–13.8** dB

12. Capacitance to circuit = **0.47** µF

    Is this value relatively close to the capacitance you calculated in Step 10?

    yes

14.

24 AWG, 6 MILES

TRANSMISSION CIRCUIT (BLOCK 6) SWITCH POSITIONS	FREQUENCY (Hz)					
	500	1K	1.5K	2K	2.5K	3K
SW601-B; SW602-C; SW603-1, DOWN SW603-2 UP	– 11	– 15	– 17	– 20	– 21	– 22
SW601-A, SW602-C; SW603-1 DOWN, SW603-2 UP	– 12	– 13	– 13	– 13	– 13	– 13
SW601-C; SW602-C; SW603-1 DOWN, SW603-2 UP	– 10	– 9	– 8	– 8	– 8	– 8

Figure 5-7

Is the loss you measured relatively close to the value you calculated in Step 10?

yes

16. Resistance = **595 Ω**

Capacitance = **0.56** µF

Attenuation = **–9.1** dB

18. What is the total amount of capacitance you have connected to the circuit?

Capacitance to circuit = **0.57** µF

Is this value relatively close to the capacitance you calculated in Step 16?

yes

20.

19 AWG, 7 MILES

TRANSMISSION CIRCUIT (BLOCK 6) SWITCH POSITIONS	FREQUENCY (Hz)					
	500	1K	1.5K	2K	2.5K	3K
SW601-B; SW602-C; SW603-1, DOWN SW603-2 UP	– 5	– 7	– 9	– 10	– 11	– 12
SW601-A, SW602-C; SW603-1 DOWN, SW603-2 UP	– 6	– 6	– 6	– 6	– 6	– 6
SW601-C; SW602-C; SW603-1 DOWN, SW603-2 UP	– 5	– 4	– 3	– 2	– 2	– 2

Figure 5-8

Is the loss you measured relatively close to the value you calculated in Step 16?

yes

INSTRUCTOR NOTES

EXERCISE 6

Two-Wire/Four-Wire Transmission

7. TP403 ≈ **1.2** Vp-p

   NOTE: This increases to approximately 1.3 Vp-p after adjustment of R405 in Step 9.)

9. Once this adjustment is made, is any portion of the transmit signal at TP403 available at the receive test point (TP401)?

   yes

   Considering typical telset operation, is the transmit signal (from the handset transmitter) normally *completely* removed from the receiver?

   no

   Why?

   Sidetone is used so the talker can hear their own voice through the receiver.

10. Is the transmit signal available at the "lines?"

    yes

    TP402 ≈ **0.5** Vp-p

11. $\text{Ratio} = \frac{V_{P-P}\,(TP403)}{V_{P-P}\,(TP402)} \approx \mathbf{1.45}$

    Signal loss ≈ **3** dBm

15. Is the CARRIER GENERATOR signal present at TP401?

    yes

Is the FUNCTION GENERATOR signal present?

yes

17. TP401 ≈ **0.5** Vp-p

18. Are both the CARRIER GENERATOR and FUNCTION GENERATOR signals present at TP402?

yes

19. Is it possible to remove the FUNCTION GENERATOR signal from TP402?

no

Why?

TP402 is a two-wire connection, which must simultaneously transmit and receive.

20. TP402 ≈ **1.3** Vp-p

21. $\text{Ratio} = \frac{V_{P-P}\,(TP402)}{V_{P-P}\,(TP401)} \approx$ **2.2**

Signal loss ≈ **7** dBm

Is the signal loss between TP402 and TP401 *greater than* or *less than* the signal loss you calculated in Step 11 (TP403 and TP402)?

greater than

Why are the signal losses you previously calculated different, even though there is no difference between the transformers?

The FUNCTION GENERATOR signal affected the entire winding of TP402, while the CARRIER GENERATOR signal affected only one-half of TP401.

23. Is the CARRIER GENERATOR signal present at TP403?

yes

24. Are you able to remove the CARRIER GENERATOR signal from TP403?

yes

Is any portion of the receive signal available at the transmitter?

no (If the circuit is balanced.)

30. C GEN (TP1013) ≈ **1.2** Vp-p

F GEN (TP1014) ≈ **1.2** Vp-p

31. Which test point is the receive terminal for the FUNCTION GENERATOR transmit signal?

F GEN RX = **TP405**

Which test point is the receive terminal for the CARRIER GENERATOR transmit signal?

C GEN RX = **TP401**

32. Can you see evidence of both the received signal from Hybrid #2, as well as, the transmitted signal from Hybrid #1?

yes

If you adjust R405, which signal will be removed — the FUNCTION GENERATOR signal, or the CARRIER GENERATOR signal?

FUNCTION GENERATOR

34. TP401 ≈ **0.2** Vp-p

35. $\text{Ratio} = \frac{V_{P-P}\,(TP1013)}{V_{P-P}\,(TP401)} \approx$ **5.85**

Signal loss ≈ **15** dBm

36. Can you see evidence of both the received signal from Hybrid #1, as well as, the transmitted signal from Hybrid #2?

yes

If you adjust R411, which signal will be removed — the FUNCTION GENERATOR signal, or the CARRIER GENERATOR signal?

CARRIER GENERATOR

38. TP405 ≈ **0.2** Vp-p

39. $\text{Ratio} = \frac{V_{P-P}\,(TP1014)}{V_{P-P}\,(TP405)} \approx$ **5.85**

Signal loss ≈ **15** dBm

Are the signal losses between the two hybrid circuits (as calculated in Step 35 and Step 39) relatively equal?

yes

40. Are both transmitted signals present?

yes

45. Is the CARRIER GENERATOR signal present?

yes

Is the FUNCTION GENERATOR signal *also* present?

yes

46. Is the FUNCTION GENERATOR signal present?

yes

Is the CARRIER GENERATOR signal *also* present?

yes

48. Has the FUNCTION GENERATOR portion of the waveform been significantly reduced?

yes

49. Are both the CARRIER GENERATOR and FUNCTION GENERATOR signals present, with significant voltage levels?

yes

56. Is the FUNCTION GENERATOR signal present?

yes

57. Is the CARRIER GENERATOR signal present?

yes

62. What happens to the amplitude of the FUNCTION GENERATOR signal as you move through its signal path?

It decreases.

When you reached TP403, which signal was much larger in amplitude?

The CARRIER GENERATOR signal.

63. What happens to the amplitude of the CARRIER GENERATOR signal as you move through its signal path?

It decreases.

When you reached TP407, which signal was much larger in amplitude?

The FUNCTION GENERATOR signal.

69. Are the signals at these two test points the same amplitude?

yes

70. Are the signals at these two test points the same amplitude?

yes

77. Is the FUNCTION GENERATOR signal currently seen at TP401?

yes

Why?

The hybrid is unbalanced.

78. Is the CARRIER GENERATOR signal beginning to increase in amplitude?

yes

79. Is the CARRIER GENERATOR signal currently seen at TP405?

yes

Why?

Again, the hybrid is unbalanced.

80. Is the FUNCTION GENERATOR signal beginning to increase in amplitude?

yes

INSTRUCTOR NOTES

EXERCISE 7

Noise and Transmission Impairments

5.

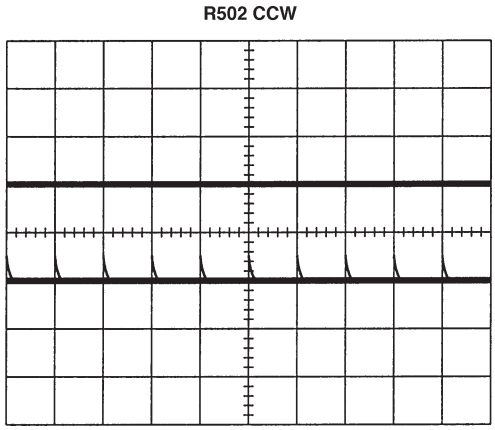

Figure 7-1A

6.

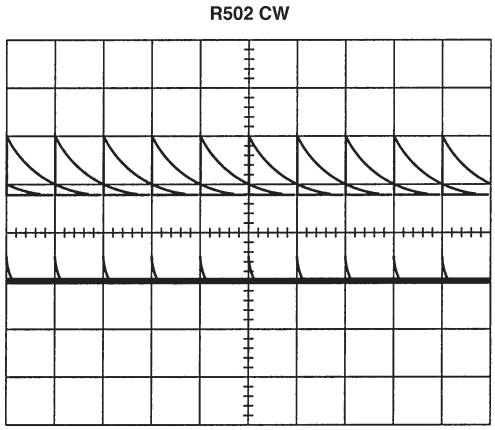

Figure 7-1B

18. Did you just set the level for the *tuned* condition, or the *detuned* condition of the filter?

detuned

19. C GEN frequency ≈ **50** kHz

    $f_C \approx$ **1000** Hz

    Based on your answer to the previous question, is the rejection filter tuned to the FUNCTION GENERATOR frequency?

yes

21. Signal level ≈ **+6** dBm

22. Which of the two inputs to the Balanced Modulator is more audibly noticeable—the FUNCTION GENERATOR signal, or the Noise Source?

FUNCTION GENERATOR

23. Signal + Noise ≈ **+7** dBm

    Can you hear the signal from the Noise Source better?

yes

24. Output ≈ **–4** dBm

    Since you have tuned the filter to the FUNCTION GENERATOR frequency, what does the power level you just measured represent?

    The noise source alone.

    Express the value you just measured in terms of dBrnC:

    Output ≈ **–4** dBm ≈ **+86** dBmC

Is the FUNCTION GENERATOR signal audibly present?

no

25. $\frac{S + N}{N} = \frac{\text{dBm (Step 23)}}{\text{dBm (Step 24)}} \approx$ **11 dB**

29. Output ≈ **+12** dBm

30. Output ≈ **–8** dBm

What is the ratio between the signal level measured in Step 29 to the level measured in Step 30?

$\frac{\text{Output (Step 29)}}{\text{Output (Step 30)}} \approx$ **20** dB

33. Output (max) ≈ **+5** dBm

34.

FREQUENCY (Hz)	50	100	200	300	400	500	600	700	800	900	1000
dBm	–29	–28	–16	–11	–8	–6	–3	–2	–1	–1	0

1500	2000	2500	3000	3500	4000	4500	5000
–2	–4	–7	–8	–10	–11	–12	–12

Figure 7-5

35.

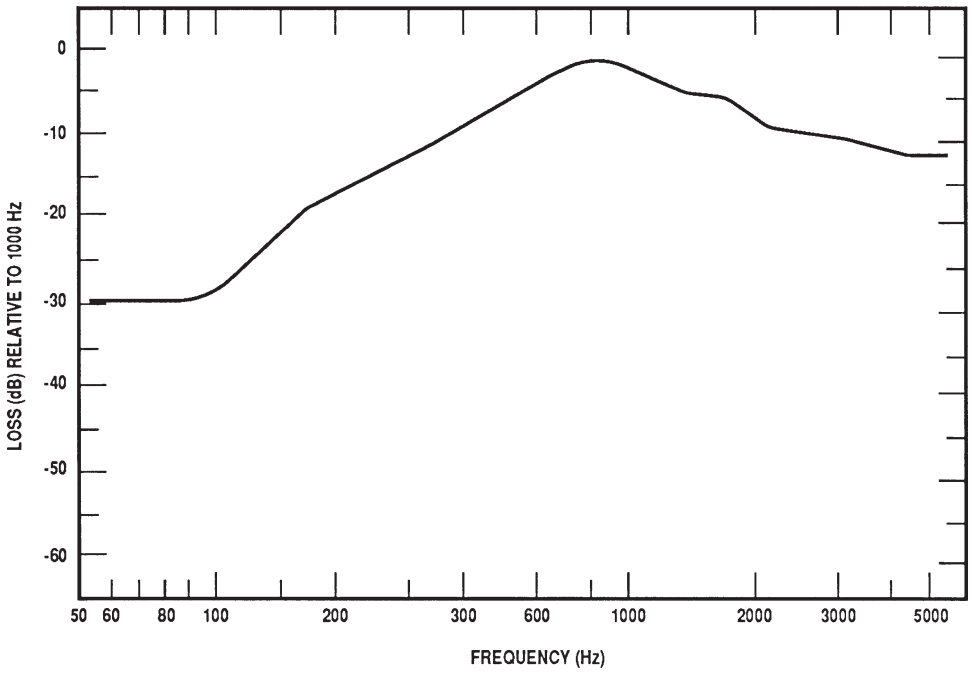

Figure 7-6

Do both graphs peak at the same point?

yes

46. Peak power = **6.67** mW

47. Average power ≈ **+4** dBm

$$\text{Average power (mW)} = \log_{-1}\left(\frac{\text{dBm}}{10}\right) \approx \textbf{2.51}\ \text{mW}$$

48. Input P/AR ≈ **2.657**

50. Is the signal present similar to the signal shown in Figure 7-8B?

yes

51. Output ≈ **1.7** Vp-p

52. Output Peak power ≈ **4.81** mW

53. Output Average power ≈ **+1** dBm

$$\text{Average power (mW)} = \log_{-1}\left(\frac{\text{dBm}}{10}\right) \approx \mathbf{1.25}\ \text{mW}$$

54. Output P/AR ≈ **3.848**

Is there a difference between the P/AR value you calculated for the input pulse (Step 48) and the P/AR value you calculated for the output pulse?

yes

55. $$\frac{\text{Input P/AR (Step 48)}}{\text{Output P/AR (Step 54)}} \times 100 \approx \mathbf{69}\ \%$$

What can you conclude about the existence of phase distortion in the test circuit, based on your previous answer?

INSTRUCTOR NOTES

SELF-TEST REVIEW ANSWERS

Section 1

CHAPTER 1

1. C — The factor that allows the PTN worldwide access is **network compatibility**.

2. B — The **talk battery** is not a part of the single-line telephone set.

3. D — The **dial pulses** do not originate from the central office.

4. A — The telephone set is not classified as **facilities**.

5. B — **Network pair** is not the correct classification for a telephone line.

6. B — One wire of the telephone line is the **ring**. It is the **red** wire, with **negative** voltage polarity.

7. A — The telset will not always operate properly below about 20 mA, regardless of the voltage. Therefore, the correct answer is **15 V, 10 mA**.

8. C — The correct transformer connection for a balanced output is **Figure C**. The center-tap is grounded, and both signal leads are above ground.

9. C — An **advisory signal** informs the caller that the dialed line is busy.

10. D — A **supervisory signal** provides telco with data for billing its customers.

11. B — A telset that is **off-hook** has a **closed hookswitch** that allows DC to flow through the telset.

12. D — The in-band frequency limits are 300 Hz to 3 kHz. The **3800 Hz** signal is out-of-band.

13. The sequence for completing a local call is as follows:

    1. **Telset off-hook; request for service. Dial tone applied.**

    2. **Time-out starts.**

    3. **Dial sequence.**

    4. **Switch to processor control with number at its dial address; switch scans lines for the local loop of called party.**

    5. **Ringer signal to called party; ringback signal to caller. Call connected when called party goes off-hook; start of call accounting circuits.**

    6. **Completion of call; on-hook results in disconnect, stopping accounting timer and restoring all circuits.**

14. A. The last four digits of the dialing number plan access **the local central office (local CO) loop**.

    B. The first three digits of the dialing number plan access **the area switch**.

    C. The second three digits of the dialing number plan access **the central office for a specific zone**.

15. The maximum capacity of the four-digit local loop numbers available from a single CO is **10,000 (10^4)**.

16. The difference between a loop and a trunk is the connection of these wire circuits. **A loop is the wire circuit between the CO and a subscriber telset; while a trunk is the circuit between the CO and another exchange**.

17. The switching center that accesses the long-haul network is called a **toll center**.

18. The switching hierarchy for the long-haul network is as follows:

    Access from the local CO with Class 5 switch, through toll-connecting trunks, to a toll center with a Class 4 switch. Access from the toll center, through inter-toll trunks, to primary centers with Class 3 switches, to sectional centers with Class 2 switches, and to regional centers to Class 1 switches.

CHAPTER 2

1. The four main physical parts of the single-line telephone set include: **the handset, the cradle, the housing, and the dial**.

2. The six main electrical parts of the single-line telephone set include: **the transmitter, the receiver, the voice network, the dial network, the hookswitch, and the ringer.**

3. **The capacitor** in the ringer network prevents (blocks) the flow of direct current through this circuit.

4. The ringer circuit is designed to be **resonant at 20 Hz or 30 Hz, but will operate over a frequency range above and below these ratings** with the application of higher AC voltages.

5. The four terminal connections of the telset's voice network are: **the line, the transmitter, the receiver, and the balance circuit**.

6. B — The voice network transformer's two receive windings are out-of-phase for the **outgoing transmit signal.**

7. B — The **outgoing transmit signal** is applied to both differential inputs of the IC voice network.

8. The standards for pulse dialing are 100 ms-per-pulse, with an interdigit interval of about 700 ms. Dialing 767-2676 has six interdigit intervals, and 41 total pulses—the sum of the numbers. The dialing time is:

   $(6 \times 700 \text{ ms}) + (41 \times 100 \text{ ms}) = 8300 \text{ ms} =$ **8.3 s**

9. The standards for DTMF dialing are 100 ms-per-digit, with no interdigit interval. 767-2676 has 7 digits; so the dialing time is 700 ms, or **0.7 s**.

10. B — From the list, all of the frequencies are correct except 750 Hz in the 750 and 1209 Hz answer. The correct frequency is **770 Hz**.

CHAPTER 3

1. The circuit between the CO and telset is generally designated the **"local loop facilities," including: multi-wire cables, termination or junction boxes, lightning protectors, terminal blocks, and jacks for telset plug-in line cords.**

2. Single-line extension telephones are connected in **parallel** with the tip and ring terminals on the telephone line.

3. The loop current for parallel connected telsets (each at 200 ohms resistance) in series with 700 ohms loop resistance, and with 48 VDC at the CO source, can be calculated as a simple series-parallel circuit as follows:

   $I_{Load} = E \div (R_{Loop} + R_{Load}) = 48 \div [\, 700 + (200 \div 3) \,] =$ **63 mA**

   $I_{Set} = I_{Load} \div$ # of telsets = 63 mA $\div$ 3 = **21 mA**

4. The ringer impedance for parallel-connected telsets that are on-hook, with ringer impedances of 3 kilohms each, can be calculated as a simple parallel circuit as follows:

   $R_{Total} = R_{Load} = (3\ k\Omega \div 4) =$ **750 Ω**

5. The four wires are colored **red, green, yellow, and black**. The primary connections are **red to ring**, and **green to tip**.

6. The inductance required of an LC bell ringer network that is resonant at 20 Hz, with a 0.5 microfarad capacitor, can be calculated as:

   $L = 1 \div [\, (2\,p)^2\, C]$

   $= 1 \div [\, (2\,p \times 20)^2 \times 5 \times 10^{-7} \,] =$ **127 H**

7. The connection for each of the following terminals are identified as follows:

   A. **is the connection of the capacitor to the ringer network.**

   B. **is the connection of the transmitter to the voice network through the 22 Ω resistor.**

   C. **is the ring network-side connection of the hookswitch.**

   F. **is the tip network-side connection of the hookswitch.**

   G. **is the ringer connection for the tip-side of the line. For a 30-Hz ringer, the jumper is connected from the tip (L1) to G.**

   K. **is the connection to the capacitor of the ringer network. For a 30-Hz ringer, the jumper is connected from the tip (L1) to K.**

   R. **is the common connection of the voice network and the handset (transmitter and receiver).**

   GN. **is the connection of the receiver to the voice network.**

   RR. **is the connection of the varistor loading circuit to the line, through R2.**

   L1. **is the tip line input terminal.**

   L2. **is the ring line input terminal.**

8. Varistors are voltage-variable resistors that have lower resistance in proportion to increased voltage levels. They are **used to shunt signals across the line and receiver terminals (reducing their level) in the presence of higher voice-signal voltages. They will make excessively loud signals quieter.**

9. S3, S3A, and S2A are wired across the receiver; **S3 and S3A short across the receiver when the telset is dialed, while S2A does the same when the hookswitch is activated.** This prevents the dial and hookswitch clicks from being heard in the receiver.

10. The range of operating limits for the telset are specified as follows:

    A. DC operating current **from 20 to 120 mA**.

    B. Local loop resistance **from 400 to 2200 ohms.**

    C. AC ringing signal voltage **from 40 to 130 VAC.**

11. The basic functional sections of the electronic telset include:

hookswitch	**bridge rectifier**
tone ringer	**voltage regulator**
voice or speech network	**DTMF/pulse dial**
receiver	**transmitter (microphone)**

12. The power supply of the electronic telset accommodates a reversal in tip/ring polarity, or misconnection, **by rectifying the negative side of the supply voltage to ground, and the positive side of the supply voltage to the voltage regulator circuit.** This is accomplished with the bridge rectifier.

13. The CO functions that are enabled by the loop relay include:

dial tone	**switching services**
ring generator	**ringback tone**
busy signal	**advisory signals**
advisory messages	**call supervision**

14. The frequencies of the CO signals are as follows:

    A. Dial tone = **350 and 440 Hz continuous**

    B. Busy = **480 and 620 Hz, 0.5 s on/off**

    C. Ringback = **440 and 480 Hz, 2 s on/4 s off**

    D. Re-order = **480 and 620 Hz, 0.3 s on/0.2 s off**

    E. Off-hook = **1400, 2000, 2500, 2600 Hz, loud 0 dBm level**

15. With two identical lines from the CO, one loop start, and one ground start, **the ground start will have the higher loop current,** because only half of the loop resistance will be used in the ground-start circuit. With loop start, the current is limited by the return-path resistance of the wire; with ground start, the current returns through ground (assumed to be zero resistance).

16. The **lineside** of the CO connects to the telset, while the trunkside of the CO connects to other CO's or to a toll exchange.

17. 2/4-wire converters are connected on the **trunkside** of the CO, as 4-wire lines are used in interoffice and toll trunks, but not in local loop circuits.

18. Signals are conditioned **by increasing their level, decreasing their level, or affecting their frequency response characteristics**.

19. **Two, 2/4-wire converters** are an integral part of two-wire line amplifiers, as the amplifiers cannot function with signals passing in two directions. The signals are separated into two directional paths, amplified, and then recombined into a two-wire circuit.

Section 2

CHAPTER 4

1. C — **SF (single-frequency) signals** are created electronically. Messages and voice signals are created acoustically, and DC signals are created electrically, but don't use oscillator circuits.

2. C — The **multivibrator** circuit is most likely to produce a square-wave signal.

3. **Positive (correct phase) feedback and an overall gain factor (feedback loss × amplifier gain) of 1.0** are required to assure that oscillation will occur in an amplifier circuit.

4. C — The feedback signal must be fed back at a phase angle of **180°**.

5. A — A series LC feedback circuit will have **0°** phase shift at its resonant frequency.

6. The voltage increases with time across **the capacitor** of an RC relaxation oscillator.

7. D — The **sawtooth wave** is the typical waveform output of an RC relaxation oscillator.

8. A — The **sine wave** is the typical waveform output of an analog RC oscillator.

9. A — The **sine wave** cannot be obtained from a multivibrator.

10. **Frequency division** is the major advantage of using multivibrators rather than analog oscillators to generate signals. The square waves produced by the multivibrator can be precisely frequency divided.

11. A — The **frequency** dimension of DTMF signals is the most critical to detect.

12. C — Loop **current** is the telephone signal that is detected by the loop relay.

13. The functional blocks of the PLL (phase-locked loop) include: **a phase detector, low-pass filter, amplifier, and voltage-controlled oscillator (VCO)**.

14. A— If two signals of identical frequency are applied to the phase detector, the detector's output voltage will be **zero**.

15. The reference frequencies for a PLL used as a tone decoder are set **with an external RC network.**

16. D — A **digital NOR gate** is driven by the dual DTMF tone decoders to detect frequency pairs.

17. B — The **comparator** is used to detect voltage levels.

18. B — With +5 VDC on the comparator's inverting input, and +2 VDC on its non-inverting input, the output is **saturated negative**. The non-inverting input is more negative than the reference.

19. B — A **comparator** is used within an IC timer to obtain switching times from a charging capacitor.

CHAPTER 5

1. Six transmission media used for communication signals include: **wires, copper cables, radio waves, microwaves, satellites, and fiberoptic cables**.

2. B — **0.5 mile of 22 gauge** wire has the highest resistance at approximately 42.61 ohms.

3. The resistance of 22 gauge wire is 16.14 ohms/1000 feet. A 5-mile loop uses 10 miles of wire (5 miles for each conductor). There are 5280 feet/mile.

   $R_{total} = 2 \times 5 \times 5280 \times 16.14 \div 1000 =$ **852 Ω**

4. The resistance of 10 miles of a 24 gauge wire-pair is calculated as:

   $R_{total} = 2 \times 10 \times 5280 \times 25.67 \div 1000 =$ **2711 Ω**

   The total current is calculated as the CO voltage divided by the sum of the loop and telset resistances:

   $I = E \div R = 48 \div (2711 + 200) =$ **16.5 mA**

5. A total of 2400 ohms circuit resistance will limit the current from a 48-volt source to 20 mA. With 200 ohms in the telset, the total allowable resistance for the 20-mile loop is 2200 ohms. The 20-mile loop has 40 miles of wire which must total 2200 ohms; therefore, the wire must have a resistance of no more than:

   $R = (2200\ \Omega \times 1000 \text{ feet}) \div (40 \text{ miles} \times 5280 \text{ feet})$

   $= 10.42 \text{ ohms}/1000 \text{ feet}$

   The smallest wire diameter that has less than 10.42 ohms/1000 feet is **20 gauge** with 10.15 ohms/1000 feet.

6. A — Since the inductance depends on the spacing-to-diameter (2s ÷ d) ratio, we solve this problem by calculating for the largest value of 2s ÷ d. By calculation, the **spacing of 0.080**, divided by the **26 gauge wire** diameter of 0.016, is the largest of the choices in the problem.

7. The problem is solved by calculation: (the diameter of 22 gauge wire is 0.025-inch.)

   $L = 1.48 \log (2s \div d) = 1.48 \log (2 \times 0.2 \div 0.025)$

   $= 1.78 \text{ mH/mile}; 1.78 \times 5 \text{ miles} =$ **8.9 mH**

8. D — Since the capacitance depends on the reciprocal spacing-to-diameter (2s ÷ d) ratio, assuming the same dielectric, we solve this problem by calculating for the smallest value of 2s ÷ d. By calculation, the **spacing of 0.220**, divided by the **16 gauge wire** diameter of 0.051, is the smallest of the choices in the problem.

9. The problem is solved by calculation: (the diameter of 22 gauge wire is 0.025-inch, and the dielectric constant of PVC is 2.7.)

   $C = 19.3\ \varepsilon \div \log (2s \div d)$

   $= (19.3 \times 2.7) \div \log (2 \times 0.2 \div 0.025) = 43.3 \text{ nF/mile};$

   $43.3 \times 5 \text{ miles} =$ **216 nF**

10. D — The load impedance that yields the smallest absolute value impedance ratio with the generator impedance will provide the highest power transfer. **900 ohms** is 1.5 times 600 ohms, while the other choices are higher ratios.

11. D — The line with the highest capacitance will have greater losses at higher frequencies. The **16 gauge** line **spaced at 0.220 inches** has the highest capacitance.

12. A — The line with the highest inductance and lowest capacitance, 26 gauge spaced at 0.080 inches in this case, will have the greatest impedance.

13. The inductance of the line is calculated as the capacitance times the square of the impedance:

$$L = Z_0^2 C = (75)^2 \times (20 \times 10^{-12}) = \mathbf{113\ nH}$$

14. The velocity factor is calculated as the inverse square root of the line insulator's dielectric constant. The dielectric constant of Teflon® (PTFE) is 2.1.

$$\text{V.F.} = 1 \div \sqrt{\varepsilon} = 1 \div \sqrt{(2.1)} = \mathbf{0.69\ or\ 69\%}$$

15. A — The line with the highest inductance, **26 gauge spaced at 0.080 inches** in this case, will have the greatest phase distortion of higher frequency signals due to the skin effect causing less inductance at higher frequencies.

16. The diameter of the 26 gauge center conductor (d) is 0.016 inch. The dielectric constant of Teflon® is 2.1. With this information, the properties of the coaxial cable can be calculated as:

$$L = 140 \log (D \div d)$$

$$= 140 \log (0.08 \div 0.016) = \mathbf{98\ \mu H/1000\ feet}$$

$$C = 7.35\ \varepsilon \div [\log (D \div d)]$$

$$= 7.35 \times 2.1 \div [\log (0.08 \div 0.016)] = \mathbf{22\ nF/1000\ feet}$$

$$Z_0 = \left(138 \div \sqrt{\varepsilon}\right) \log (D \div d)$$

$$= \left(138 \div \sqrt{2.1}\right) \log (0.08 \div 0.016) = \mathbf{66.5\Omega}$$

CHAPTER 6

1. B — The transmission line has electrical properties equivalent to a network of **series R, series L, and shunt C**.

2. Without the capacitor, the 1700 ohms of series resistance will drop the source voltage by a factor proportional to the resistance values of the source, line, and load. (We'll neglect the series reactance, as it is insignificant in proporiton to the series resistance.)

$$V_{LOAD}(W/O\ cap) = V_{OC}\ [\ R_{LOAD} \div\ (R_{G\ EN} + Z_{SER} + R_{LOAD}\ )\ ]$$

$$= 2\ [600 \div (\ 600 + 1700 + 600\ ) = \mathbf{0.42\ V}$$

$$Loss_{dB} = 20 \log \left(\frac{V_{LOAD}}{V_{OC}} \right) = 20 \log \left(\frac{0.42}{2} \right) = \mathbf{-14\ dB}$$

Now we'll repeat the calculation with the capacitor's reactance (104 ohms) shunting the 600-ohm load resistance down to about 100 ohms:

$$V_{LOAD}(W/cap) = V_{OC}\ [\ Z_{LOAD} \div\ (\ R_{GEN} + Z_{SER} + Z_{LOAD}\ )]$$

$$= 2\ [100 \div\ (600 + 1700 + 100) = \mathbf{0.08\ V}$$

The signal loss that results from the effects of the capacitor is calculated in dB, as:

$$Loss_{dB} = 20 \log \left(\frac{V_{LOAD}}{V_{OC}} \right) = 20 \log \left(\frac{0.08}{2} \right) = \mathbf{-28\ dB}$$

3. With the loading coil in the circuit, the effective impedance of the load looks like 600 ohms shunted by only 1040 ohms of capacitive reactance. The load impedance is about 520 ohms. The approximate load voltage is calculated as:

$$V_{LOAD}(W/coil) = V_{OC}\ [Z_{LOAD} \div\ (R_{GEN} + Z_{SER} + Z_{LOAD})]$$

$$= 2\ [\ 520 \div (\ 600 + 1700 + 520\ )] = \mathbf{0.36\ V}$$

The signal loss is calculated in dB, with the capacitor and the coil in the circuit, as:

$$\text{Loss}_{dB} = 20 \log \left(\frac{V_{LOAD}}{V_{OC}} \right) = 20 \log \left(\frac{0.36}{2} \right) = \mathbf{-15\ dB}$$

The addition of the loading coil reduced the loss from –28 dB with the capacitor, to –15 dB. This is an effective decrease in loss of 13 dB. Therefore, the loading coils cancel the effects of the line's shunt capacitance, and improve its frequency response at the expense of only about 1 dB (–14 dB without the capacitor, to –15 dB with the capacitor and the coil.

4. The gain of an amplifier will need to be 20 dB at 3 kHz, and 12 dB at 1 kHz to compensate for the corresponding losses in the transmission line.

5. The conditioning types are listed as follows:

   __**D**__ A. Signal-to-noise.

   __**C**__ B. Signal power.

   __**C**__ C. Frequency response.

   __**D**__ D. Harmonic distortion.

   __**C**__ E. Attenuation distortion.

   __**C**__ F. Envelope delay distortion.

   __**D**__ G. Intermodulation distortion.

   __**C**__ H. Phase delay.

   __**D**__ I. Circuit linearity.

6. The values of **resistance and inductance** change with frequency due to the skin effect, where **higher frequency currents are confined to flowing primarily along the surface "skin" of a wire**.

7. Telco's standard references for frequency, power, and impedance are **1 kHz (1004 Hz), 0 dBm (1 mW), and 600 ohms**.

8. Refer to Table 6-1 in the Textbook to obtain allowable levels of noise in transmission circuits. For the **70-mile distance, the noise level is –59 dBm**, and for the **500-mile distance, the noise level is –55 dBm**. A greater noise level is allowed for shorter lengths of line where signal levels are also higher.

9. The specification for C-notched noise is **24 dB** for standard voice transmission circuits, and 28 dB for high-performance voice circuits.

10. A level specification of –16 dBm TLP is 4 dB higher than the signal measured to that reference (–4 dBmO). The true power level of the signal is **–20 dBm** — 4 dB below the TLP reference.

11. A noise level of +53 dBrnC is 53 dB above the level of rn at –90 dBm. The level is:

    dBm = rn + dBrnC = (–90) + (+53) = **–37 dBm**

12. The S/N for Problems 45 and 46 is:

    (–20 dBm) – (–37 dBm) = **17 dB**

13. **Refer to Figure 6-5 in the text** for the block diagram of the set-up required to measure frequency response and attenuation.

14. **Refer to Figure 6-6 in the text** for the block diagrams of the set-up required to measure C-message and C-notched noise.

15. **Refer to Figure 6-7 in the text** for the block diagrams of the set-up required to measure harmonic and intermod distortion.

16. The peak-to-average value (P/AR) becomes lower with longer circuit paths, **as the inductance and capacitance increase, integrating and spreading the applied pulse waveform**.

17. The applied pulse waveform is integrated and spread in proportion to non-linearities in a circuit's inductance and capacitance—factors that affect envelope delay in transmission circuits.

Section 3

CHAPTER 7

1. B — To access an outside line with a key telephone system, you **press a button to manually select a particular line**.

2. A — **True**. Key telephone systems are not generally classified as switches.

3. D — If you have twelve telsets in a typical telephone system, you should normally have **3** outside lines.

4. A — A **key system** uses a KSU.

5. B — The **station cards** process the control signals between telsets and the CPU.

6. B — You **dial 9** to access an outside line with a PBX system.

7. D — **All of the above**. In a PBX system, which of the following statements is true? (A)Trunks can be set up to allow only incoming calls. (B)Trunks can be set up to allow only outgoing calls. (C)Trunks can be set up to allow a combination of incoming and outgoing calls.

8. A — In the telephone industry, POTS is a **plain old telephone system**.

9. B — **False.** In a PBX system, the PBX does not get its own dial tone from the CO.

10. C — A **KSU** is not present in a PBX system.

11. A — The main purpose of a CODEC is **to convert analog to digital**.

12. D — **All of the above**. Which of the following statements is true? (A)Wireless PBXs allow you to carry your PBX-type phone with you. (B)Base stations are used to improve the coverage of a wireless PBX phone within a business. (C)Some wireless PBX portable phones can automatically switch to a cellular system when they are out of range of a PBX base station.

13. A — **True**. Centrex switching equipment is usually located at the CO.

14. B — **The telephone company** owns the switching equipment in a Centrex system.

CHAPTER 8

1. C — Cellular telephones use the frequency ranges **824–849 and 869–894 MHz**.

2. C — **416** channel pairs are assigned to each cellular company in a given area.

3. A — Persons who use a cellular telephone in service area other than their own are called **roamers**.

4. C — **7** cells are typically grouped together in a system.

5. B — When a cell is split into two or more new cells, the diameter of the new cells are **half the diameter of the original cell**.

6. A — **Registration** occurs when a mobile cell phone transmits its electronic serial number and phone number to a cellular base station at power-up.

7. C — When you roam into an area that is serviced by a carrier other than the one it has been preprogrammed for **the Roam indicator will flash**.

8. D — The **MTSO** is not part of a cell phone mobile installation.

9. C — **3** vertical elements generally make up a cellular base station's antenna system.

10. D — **All of the above. Hills, mountains, and buildings** can cause dead spots and dropouts.

11. A — **True**. Moisture in the air can affect cellular telephone operation.

12. B — **False**. The frequencies used by cellular phones **can be** intercepted.

13. D — The frequency band **1850 – 1990 MHz** is used for broadband and unlicensed PCS operation.

14. D — **All of the above.** (A)Smaller size. (B)Lower battery consumption. (C)Transmission are more secure.

SECTION EXAMINATION AND ANSWERS

Section 1 Examination

1. Which is the primary factor that allows the PTN world-wide access?

   A. Satellite networks.
   B. Network compatibility.
   C. Digital signal processing.
   D. Electronic switching systems.

2. Which component supplies power from the central office to operate the telset at the subscriber location?

   A. Hookswitch.
   B. Transmitter.
   C. Transducer.
   D. Talk battery.

3. The signals used to inform a caller of the condition of their line are called:

   A. advisory signals.
   B. address signals.
   C. supervisory signals.
   D. message signals.

4. For which signal are the voice network transformer's two receive windings out-of-phase?

   A. Signal at the receiver.
   B. Outgoing transmit signal.
   C. Incoming line receive signal.
   D. Signal at the balance circuit.

5. Using the standards for pulse dialing, what is the approximate time required of an automatic dialer to call the number, 555-1212?

   A. 3 seconds.
   B. 6 seconds.
   C. 9 seconds.
   D. 12 seconds.

6. Using the standards for DTMF dialing, what is the approximate time required of an automatic dialer to call the number, 555-1212?

   A. 0.5 seconds.
   B. 0.6 seconds.
   C. 0.7 seconds.
   D. 0.8 seconds.

7. The small amount of transmit voice signal that is heard in the telset receiver is referred to as the:

   A. advisory signal.
   B. anti-tinkle.
   C. feedback.
   D. sidetone.

8. Which class of switch in the "switching hierarchy" is designated for use at the toll centers?

   A. Class 4.
   B. Class 3.
   C. Class 2.
   D. Class 1.

9. List the six-step sequence of correctly completing a local call to a line that is not busy.

   (1) _____

   (2) _____

   (3) _____

   (4) _____

   (5) _____

   (6) _____

10. Identify the exchanges accessed by the following:

    A. Last four digits of the dialing numbering plan.
    _____

    B. First three digits of the dialing numbering plan.
    _____

    C. Second three digits of the dialing numbering plan.
    _____

11. List the four main physical parts of the single-line telephone set.

    _____ _____

    _____ _____

12. List the six main electrical parts of the single-line telephone set.

    _____ _____

    _____ _____

    _____ _____

13. List the four terminal connections of the telset's voice network.

    _____ _____

    _____ _____

14. List the parts or designations for each of the wiring connections between the CO and telset.

    _____

    _____

    _____

    _____

    _____

15. What is the calculated loop current for each of two parallel-connected telsets, if they are simultaneously off-hook, with a 48-VDC CO and 1200 ohms of loop resistance?

    _____

16. What is the ringer impedance of three parallel connected telsets that are on-hook, if the impedance of each ringer is 6 kilohms, set for 20 Hz operation? _____

17. List the four insulator colors of 4-conductor station wire, and identify which two are primarily used for the tip and ring connections to the telephone line.

    _____ _____

    _____ _____

18. What is the calculated inductance (L) required of an LC bell ringer network, resonant at 30 Hz, if the capacitor is 0.4 microfarads?

    _____

19. List the range of operating limits for the telset and local loop for the following specifications:

    A. Telset DC operating current. _____

    B. Local loop resistance. _____

    C. AC ringing signal voltage. _____

20. List the CO functions that are enabled by the loop relay:

    _____ _____

    _____ _____

    _____ _____

    _____ _____

Section 1 Examination Answers

1. B — **Network compatibility** is the primary factor that allows the PTN world-wide access.

2. D — The **talk battery** supplies power from the central office to operate the telset at the subscriber location.

3. A — The signals used to inform a caller of the condition of their line are called **advisory signals**.

4. B — The voice network transformer's two receive windings are out-of-phase for the **outgoing transmit signal**.

5. B — The standards for pulse dialing are 100 milliseconds-per-pulse, with an interdigit interval of about 700 milliseconds. Dialing 555-1212 has 6 interdigit intervals (4200 milliseconds), and 21 total pulses (2100 milliseconds), for a dialing time of 6300 milliseconds, or **6.3 seconds**.

6. C — The standards for DTMF dialing are 100 milliseconds-per-digit, with no interdigit interval. The number 555-1212 has 7 digits; so the dialing time is 700 milliseconds, or **0.7 second**.

7. D — The small amount of transmit voice signal that is heard in the telset receiver is referred to as the **sidetone**.

8. A — **Class 4** switches are designated for use at the toll centers.

9. The sequence of completing a local call is as follows:

   (1) Telset off-hook; request for service. Dial tone applied.
   (2) Time-out starts.
   (3) Dial sequence.
   (4) Switch to processor control with number at its dial address; switch scans lines for the local loop of called party.
   (5) Ringer signal to called party; ringback signal to caller. Call connected when called party goes off-hook; start of call accounting circuits.
   (6) Completion of call; on-hook results in disconnect; stopping accounting timer and restoring all circuits.

10. A. The exchange accessed by the last four digits of the dialing number plan are applied to **the local central office (local CO) loop**.

    B. The exchange accessed by the first three digits of the dialing number plan are applied to **another area beyond the zones served by local central offices**.

    C. The exchange accessed by the second three digits of the dialing number plan are applied to **another central office in another zone from the local CO**.

11. The four main physical parts of the single-line telephone set include: the **handset, the cradle, the housing, and the dial.**

12. The six main electrical parts of the single-line telephone include: the **transmitter transducer, the receiver transducer, the voice network, the dial network, the hookswitch, and the ringer**.

13. The four terminal connections of the telset's voice network are: **the line, the transmitter, the receiver, and the balance circuit**.

14. The parts of the circuit between the CO and telset are generally designated as **local loop facilities; including: multi-wire cables, termination or junction boxes, lightning protectors, terminal blocks, and jacks for telset line cords**.

15. The loop current for two parallel connected telsets (each at 200 ohms resistance) in series with 1200 ohms loop resistance, and with 48 VDC at the CO source, can be calculated as a simple series-parallel circuit as follows:

    $I_{Load} = E \div (R_{Loop} + R_{Load}) = 48 \div [\ 1200 + (200 \div 2\ )] = 37$ mA

    $I_{Set} = I_{Load} \div$ # of telsets = 37 mA $\div 2 =$ **18.5 mA**

16. The ringer impedance for three parallel-connected telsets that are on-hook, with ringer impedances of 6 kilohms each, can be calculated as a simple parallel circuit as follows:

    $R_{tot} = R_{par} = (\ 6k \div 3\ ) =$ **2000 Ω**

17. The four wires are colored **red, green, yellow, and black**. The primary connections are **red to ring**, and **green to tip**.

18. The inductance required of an LC bell ringer network that is resonant at 30 Hz, with a 0.4 microfarad capacitor, can be calculated as:

    $L = 1 \div [(2 \pi f)^2 C]$

    $= 1 \div [(2 \pi \times 30)^2 \times 4 \times 10^{-7}) =$ **70 H**

19. The range of operating limits for the telset and local loop are specified as follows:

    A. DC operating current **from 20 to 120 mA**.

    B. Local loop resistance **from 400 to 2200 ohms**.

    C. AC ringing signal voltage **from 40 to 130 VAC**.

20. The CO functions that are enabled by the loop relay include:

dial tone	**switching services**
ring generator	**ringback tone**
busy signal	**advisory signal**
advisory messages	**call supervision**

Section 2 Examination

1. The relaxation oscillator's output waveform is a:

   A. sine wave.
   B. square wave.
   C. triangle wave.
   D. sawtooth wave.

2. What are the two criteria required to assure that oscillation will occur using an amplifier circuit?

   _____

   _____

3. Across which component of a simple RC relaxation oscillator will the voltage increase with time? _____

4. What is the major advantage of using multivibrators rather than analog oscillators to generate signals?

   _____

   _____

5. An amplifier that is intentionally configured with a feedback loop to create output signals by regeneration is referred to as:

   A. a comparator.
   B. an oscillator.
   C. a multivibrator.
   D. an operational amplifier.

6. Which circuit can be used to produce a digital signal?

   A. Comparator.
   B. LC oscillator.
   C. Multivibrator.
   D. Relaxation oscillator.

7. What type of oscillators use piezoelectric crystals, vibrating at an exact frequency, to assure precise operating frequencies?

   A. Tunable oscillators.
   B. Stabilized oscillators.
   C. Piezoelectric oscillators.
   D. Voltage-controlled oscillators.

8. What device can be used to precisely detect voltage levels?

   A. Comparator.
   B. Multivibrator.
   C. Phase-locked loop.
   D. Voltage-controlled oscillator.

9. The total resistance of a wire is:

   A. directly proportional to its diameter.
   B. inversely proportional to its diameter.
   C. inversely proportional to its length.
   D. directly proportional to its circumference.

10. In wire transmission systems, the effect of higher frequencies traveling faster than lower frequencies is referred to as:

    A. envelope delay.
    B. phase distortion.
    C. mismatch loss.
    D. line loss.

11. A 50-ohm coaxial line has a specified distributed capacitance value of 30 pF/ft. Calculate its distributed inductance. _____ nH/ft.

12. Calculate the velocity factor of a transmission line with a dielectric insulation of polyethylene. _____

13. A transmission line has a 6 dB signal loss at 1 kHz, and a 16 dB loss at 3 kHz. Specify the operating characteristics of an amplifier that can be used to compensate for the line losses.

    _____

14. The technique called "line loading" is used to compensate for the shunt effects of _____ in transmission lines, by using additional inductors in series with the wires.

    A. delay
    B. resistance
    C. inductance
    D. capacitance

15. Which conditioning standard is used for transmission circuits carrying data and higher-quality voice signals?

    A. Loading.
    B. Frequency response.
    C. C-type conditioning.
    D. D-type conditioning.

16. The minimum acceptable P/AR is:

    A. 30.
    B. 40.
    C. 50.
    D. 60.

17. The input to an amplifier in a transmission circuit is specified for a signal level of –12 dBm TLP. The signal at that point is measured at a level of +4 dBmO. What is the power level of the signal in dBm? _____ dBm

18. A noise power level is specified at +48 dBrnC. What is the power level of the noise in dBm? _____ dBm

19. What is the S/N (in dB) for the operating values calculated in Questions 17 and 18? _____ dB

20. Transmitting a 1 kHz signal into one end of a circuit, and using a 1 kHz notch filter to remove that signal on the other end of the circuit prior to it entering a noise measuring power meter, is the test set-up for what test?

    A. P/AR.
    B. Envelope delay.
    C. C-notched noise.
    D. D-notched noise.

Section 2 Examination Answers

1. D — The relaxation oscillator's output waveform is a **sawtooth wave**.

2. The two criteria required to assure that oscillation will occur using an amplifier circuit are **feedback in correct phase, with net gain/loss equal to 1.0**.

3. Voltage will increase with time across the **capacitor** of a simple RC relaxation oscillator.

4. The major advantage of using multivibrators rather than analog oscillators to generate signals is that **the square wave signals generated by multivibrators can be easily and accurately frequency divided**.

5. B — An amplifier that is intentionally configured with a feedback loop to create output signals by regeneration is referred to as **an oscillator**.

6. C — A **multivibrator** can be used to produce a digital signal.

7. B — **Stabilized oscillators** use piezoelectric crystals, vibrating at an exact frequency, to assure precise operating frequencies.

8. A — **A comparator** can be used to precisely detect voltage levels.

9. B — The total resistance of a wire is **inversely proportional to its diameter**.

10. B — In wire transmission systems, the effect of higher frequencies traveling faster than lower frequencies is referred to as **phase distortion**.

11. A 50-ohm coaxial line has a specified distributed capacitance value of 30 pF/ft. Its distributed inductance is calculated as:

    $L = Z_0^2\, C = 50^2 \times (30 \times 10^{-12}) =$ **75 nH/ft**

12. The velocity factor of a transmission line with dielectric insulation of polyethylene is calculated as:

    $V.F. = 1 \div \sqrt{2.25} =$ **0.67 or 67%**

13. The gain of an amplifier will need to be **16 dB at 3 kHz**, and **6 dB at 1 kHz** to compensate for the corresponding losses in the transmission line.

14. D — The technique called "line loading" is used to compensate for the shunt effects of **capacitance** in transmission lines, by using additional inductors in series with the wires.

15. D — The **D-type conditioning** standard is used for transmission circuits carrying data and higher-quality voice signals.

16. C — The minimum acceptable P/AR is **50**.

17. The input to an amplifier in a transmission circuit is specified for a signal level of –12 dBm TLP. The signal at that point is measured at a level of +4 dBmO. The power level of the signal is calculated as:

    $Signal_{dBm}$ = (dBm TLP) + dBmO = (–12) + (+4) = **– 8 dBm**.

18. A noise power level is specified at +48 dBrnC. The power level of the noise is calculated as:

    $Noise_{dBm}$ = rn + dBrnC = (–90) + (+48) = **–42 dBm**.

19. The S/N for the operating values calculated in Questions 17 and 18 are calculated as:

    S/N_{dB} = [(dBm TLP) + dBmO] – (rn + dBrnC)

    = (– 8 dBm) – (– 42 dBm) = **34 dB**

20. C — Transmitting a 1 kHz signal into one end of a circuit, and using a 1 kHz notch filter to remove that signal on the other end of the circuit prior to it entering a noise measuring power meter, is the test set-up for **C-notched noise**.

Section 3 Examination

1. How do you gain access to an outside line with a key telephone system?

   A. Just lift the handset from its cradle.
   B. Dial a "9".
   C. Lift the handset from the cradle and inform the operator that you want to make an outside call.
   D. Press a button to manually select a particular unused outside line.

2. How many outside lines should you normally have in a key telephone system which consists of 24 telsets?

   A. 4
   B. 6
   C. 12
   D. 24

3. How do you gain access to an outside line with a PBX telephone system?

   A. Dial a "9".
   B. Press a button to manually select an outside line.
   C. Just lift the handset from its cradle.
   D. Dial "O".

4. In a PBX system, where does the dial tone come from when you first lift the handset?

   A. It is generated internally by the PBX.
   B. From the CO.
   C. It is generated inside each telset.
   D. There is no dial tone in a PBX system until you access an outside line.

5. What does a CODEC do?

   A. It converts digital to analog.
   B. It converts analog to digital.
   C. It provides security during a telephone conversation.
   D. It converts one digital signal to another digital signal.

6. Where is the switching equipment in a Centrex system usually located?

   A. Where it was manufactured.
   B. At the business.
   C. At the telephone company.
   D. On the nearest telephone pole.

7. What frequency range do mobile cell phones transmit?

   A. 824–849 MHz.
   B. 869–880 MHz.
   C. 880–890 MHz.
   D. 880–894 MHz.

8. The Advanced Mobile Phone Service (AMPS) is a/an:

   A. digital system.
   B. AM system.
   C. analog system.
   D. single-sideband system.

9. What type of system allows you to talk and listen at the same time?

   A. Simplex.
   B. Full-duplex.
   C. Half-simplex.
   D. Half-duplex.

10. In a cellular system, adjacent cells are assigned:

    A. the same group of channels.
    B. the same group of frequencies.
    C. a different cell number.
    D. a different group of channels.

11. Which of the following is the heart of a cell phone?

    A. The radio/logic unit.
    B. The handset/control head.
    C. The control/switching circuitry.
    D. The antenna system.

12. Which of the following PCS frequency ranges is used for unlicensed, short-range communications purposes?

    A. 1850–1910 MHz.
    B. 1910–1930 MHz.
    C. 1930–1990 MHz.
    D. 1850–1990 MHz.

Section 3 Examination Answers

1. D — You **press a button to manually select a particular unused outside line** to gain access to an outside line with a key telephone system.

2. B — You should normally have **6** outside lines in a key telephone system which consists of 24 telsets.

3. A — You **dial a "9"** to gain access to an outside line with a PBX telephone system.

4. A — In a PBX system, the dial tone **is generated internally by the PBX**.

5. B — A CODEC **converts analog to digital**.

6. C — The switching equipment in a Centrex system usually located **at the telephone company**.

7. A — Mobile cell phones transmit in the frequency range of **824–849 MHz**.

8. C — The Advanced Mobile Phone Service (AMPS) is an **analog system**.

9. B — A **full-duplex** system allows you to talk and listen at the same time.

10. D — In a cellular system, adjacent cells are assigned **a different group of channels**.

11. A — **The radio/logic unit** is the heart of a cell phone.

12. B — The PCS frequency range **1910–1930 MHz** is used for unlicensed, short-range purposes.

FINAL EXAMINATION

1. Which component is **not** a part of the single-line telephone set?

   A. Talk battery.
   B. Hookswitch.
   C. Transmitter.
   D. Voice network.

2. Which of the following does **not** originate from the central office?

   A. Dial tone.
   B. Dial pulses.
   C. Talk battery.
   D. Ringback tone.

3. Which of the following is **not** a correct classification for a telephone set?

   A. Terminal equipment.
   B. Telset.
   C. Facilities.
   D. Instrument.

4. Which is correct for one wire of the telephone line?

   A. Tip, red, positive.
   B. Tip, red, negative.
   C. Ring, red, negative.
   D. Ring, red, positive.

5. Under which voltage and current conditions will the telephone set not properly operate?

   A. 10 volts, 10 milliamps.
   B. 10 volts, 20 milliamps.
   C. 40 volts, 40 milliamps.
   D. 40 volts, 80 milliamps.

6. Which type of signaling signal provides data on calls for billing telco's customers?

   A. Voice signal.
   B. Supervisory signal.
   C. Address signal.
   D. Advisory signal.

7. Which condition is correct, and allows direct current to flow through the telephone set?

   A. On-hook, open hookswitch.
   B. Off-hook, open hookswitch.
   C. On-hook, closed hookswitch.
   D. Off-hook, closed hookswitch.

8. Which of the following signals is **not** heard by the caller or called parties?

   A. Dial tone.
   B. Ringback.
   C. Circuit congestion.
   D. E & M.

9. On voice frequency lines, which of the following frequencies is out-of-band?

   A. 600 Hz.
   B. 3600 Hz.
   C. 3000 Hz.
   D. 2800 Hz.

10. In the ten-digit number (212) 425-7033, which group of digits accesses the central office for a specific zone?

    A. 212
    B. 425
    C. 7033
    D. None of them.

11. What is the maximum number of subscribers that can be handled by a single central office using four digits?

    A. 10,000
    B. 9,999
    C. 1,999
    D. Infinite.

12. Given the standards for pulse and DTMF dialing, what is the approximate ratio of time savings achieved by the DTMF system?

    A. 10:1
    B. 5:1
    C. 3:1
    D. 2:1

13. Which frequencies are **not** used for DTMF dialing?

    A. 697 and 1336 Hz.
    B. 770 and 1209 Hz.
    C. 852 and 1427 Hz.
    D. 941 and 1633 Hz.

14. Which of the following tones are generated by a DTMF 5?

    A. 697 Hz and 1209 Hz.
    B. 852 Hz and 1477 Hz.
    C. 770 Hz and 1209 Hz.
    D. 770 Hz and 1336 Hz.

15. Which of the following functions are **not** initiated by the loop relay?

    A. Dial tone.
    B. Line seizure.
    C. Talk battery.
    D. Access to CO switch.

16. Which are the approximate resistance/impedance values for the basic telset and its circuits?

    A. 600 ohms DC, 200 ohms at 1 kHz, 6 kilohms ringer.
    B. 200 ohms DC, 600 ohms at 1 kHz, 6 kilohms ringer.
    C. 600 ohms DC, 200 ohms at 1 kHz, 3 kilohms ringer.
    D. 200 ohms DC, 600 ohms at 1 kHz, 1 kilohms ringer.

17. Which of the following frequencies is within the limits of a basic telset's ringing signal?

    A. 100 Hz.
    B. 50 Hz.
    C. 1000 Hz.
    D. 500 Hz.

18. Which of the following frequencies corresponds to the central office dial tone signal?

    A. 350 Hz and 440 Hz.
    B. 480 Hz and 620 Hz.
    C. 200 to 400 Hz.
    D. 1.4 kHz, 2 kHz, 2.5 kHz, and 2.6 kHz.

19. Where is a 2/4-wire converter most likely to be found?

    A. Between a subscriber's phone and the CO.
    B. Between a 4-wire toll switch and an amplifier.
    C. Inside a subscriber's phone.
    D. Between a CO and a 4-wire toll switch.

20. Which class of switch in the "switching hierarchy" is designated for use in the central office?

    A. Class two.
    B. Class three.
    C. Class four.
    D. Class five.

21. Which insulation colors are used in 4-conductor station wire?

    A. Red, green, black, and yellow.
    B. Red, black, blue, and green.
    C. Red, white, black, and green.
    D. Red, green, blue, and yellow.

22. What is the frequency of the ringer signal applied to the single-line telset?

    A. 10 Hz.
    B. 20 Hz.
    C. 50 Hz.
    D. 60 Hz.

23. At what voltage does the ringer signal originate from the CO?

    A. 24 volts.
    B. 48 volts.
    C. 90 volts.
    D. 120 volts.

24. What is a practical value of loop resistance found in CO circuits connected to single-line telsets?

    A. 100 ohms.
    B. 1000 ohms.
    C. 10,000 ohms.
    D. 100,000 ohms.

25. Which circuit is more likely to produce a sine-wave signal?

    A. Relaxation oscillator.
    B. LC oscillator.
    C. Multivibrator.
    D. Comparator.

26. Which circuit is more likely to produce a square-wave signal?

    A. Relaxation oscillator.
    B. LC oscillator.
    C. Multivibrator.
    D. Comparator.

27. What is the typical waveform output from a simple RC relaxation oscillator?

    A. Sine wave.
    B. Square wave.
    C. Sawtooth wave.
    D. Triangle wave.

28. Which dimension of DTMF signals is the most critical to detect?

    A. Time
    B. Power
    C. Current
    D. Frequency

29. Which telephone signal is detected by the loop relay?

    A. Time
    B. Power
    C. Current
    D. Frequency

30. If two signals of identical frequency are applied to the phase detector, the detector's output voltage will be:

    A. proportional to the applied signal voltages.
    B. saturated negative.
    C. saturated positive.
    D. zero.

31. What component is driven by the dual DTMF tone decoders to detect the frequency pairs for each of the dial digits?

    A. Differential amplifier.
    B. Digital NOR gate.
    C. Digital flip-flop.
    D. Comparator.

32. What component is often used to accurately detect voltage levels in communication systems?

    A. Differential amplifier.
    B. Digital flip-flop.
    C. Digital NOR gate.
    D. Comparator.

33. Which component is used within the IC timer to obtain precise switching times from a charging capacitor?

    A. Differential amplifier.
    B. Digital flip-flop.
    C. Digital NOR gate.
    D. Comparator.

34. Which wire has the highest resistance?

    A. 2 miles of 16 gauge.
    B. 1 mile of 19 gauge.
    C. 0.5 mile of 22 gauge.
    D. 1000 feet of 26 gauge.

35. What is the smallest wire diameter (gauge) that can be used for a 10-mile loop to provide at least 20 mA DC from a 48-volt current source, if the DC telset resistance is 200 ohms?

    A. 21 gauge.
    B. 22 gauge.
    C. 23 gauge.
    D. 24 gauge .

36. Which transmission line will have the greatest inductance?

    A. 16 gauge spaced at 0.220-inch on-center.
    B. 19 gauge spaced at 0.160-inch on-center.
    C. 22 gauge spaced at 0.120-inch on-center.
    D. 26 gauge spaced at 0.080-inch on-center.

37. Which transmission line will have the greatest capacitance (assume the same dielectric for each)?

    A. 16 gauge spaced at 0.220-inch on-center.
    B. 19 gauge spaced at 0.160-inch on-center.
    C. 22 gauge spaced at 0.120-inch on-center.
    D. 26 gauge spaced at 0.080-inch on-center.

38. A signal generator has a source impedance of 600 ohms. Which load impedance will provide for the highest power transfer from source-to-load?

    A. 100 ohms.
    B. 150 ohms.
    C. 200 ohms.
    D. 900 ohms.

39. Which transmission line will have the greatest attenuation of higher-frequency signals (assume the same dielectric for each)?

    A. 26 gauge spaced at 0.080-inch on-center.
    B. 22 gauge spaced at 0.120-inch on-center.
    C. 19 gauge spaced at 0.160-inch on-center.
    D. 16 gauge spaced at 0.220-inch on-center.

40. Which transmission line will have the highest characteristic impedance (assume the same dielectric for each)?

    A. 26 gauge spaced at 0.080-inch on-center.
    B. 22 gauge spaced at 0.120-inch on-center.
    C. 19 gauge spaced at 0.160-inch on-center.
    D. 16 gauge spaced at 0.220-inch on-center.

41. Which transmission line will have the greatest phase distortion of higher-frequency signals?

    A. 26 gauge spaced at 0.080-inch on-center.
    B. 22 gauge spaced at 0.120-inch on-center.
    C. 19 gauge spaced at 0.160-inch on-center.
    D. 16 gauge spaced at 0.220-inch on-center.

42. Which of the following is most immune to interference from when placed adjacent to other cables or wires?

    A. Two closely-spaced wires.
    B. A twisted pair.
    C. Coaxial cables.
    D. A 4-wire cable.

43. The transmission line has electrical properties equivalent to a network of:

    A. series R, shunt L, and shunt C.
    B. shunt R, series L, and shunt C.
    C. series R, series L, and shunt C.
    D. series R, shunt L, and series C.

44. What component is used to compensate for the frequency response and power losses of transmission lines?

    A. Equalizer.
    B. Capacitor.
    C. Loading coil.
    D. Electronic amplifier.

45. A loading coil is placed in a transmission line to cancel the effects of the line's:

    A. inductance.
    B. capacitance.
    C. power losses.
    D. load impedance.

46. Which two of the electrical properties of a transmission line change in proportion to frequency, due to skin effect?

    A. R and C.
    B. R and L.
    C. L and C.
    D. R, L, and C.

47. D-conditioning applies to which of the following specifications?

    A. S/N and harmonic distortion.
    B. Power and frequency response.
    C. Attenuation and phase delay.
    D. S/N and phase delay.

48. What are telco's standard frequency, power, and impedance reference levels for terminal equipment?

    A. 1 kHz, 0 dBm, and 500 ohms.
    B. 800 Hz, 0 dBm and 600 ohms.
    C. 1 kHz, 0 dBm, and 600 ohms.
    D. 1 kHz, –6 dBm, and 600 ohms.

49. With an amplifier input specified for –10 dBm TLP, and a measured input signal of +4 dBmO, what is the power level of the signal in dBm?

    A. –10 dBm.
    B. –6 dBm.
    C. –4 dBm.
    D. +4 dBm.

50. Noise power is specified as +40 dBrnC. What is the power level in dBm?

    A. –20 dBm.
    B. –30 dBm.
    C. –40 dBm.
    D. –50 dBm.

51. Which of the following process the control signals between key telsets and the CPU?

    A. Station cards.
    B. Line cards.
    C. Trunk cards.
    D. Intercom cards.

52. Which of the following is **not** present in a PBX system?

    A. Analog and digital cards.
    B. Trunk cards.
    C. Data cards.
    D. KSU.

53. What do the letters POTS refer to in the telephone industry?

    A. PBX-only telephone system.
    B. Private-onsite telephone system.
    C. Plain old telephone system.
    D. Personal online telephone system.

54. How many pairs of channels are assigned for cellular use?

    A. 333.
    B. 416.
    C. 832.
    D. 666.

55. How many simultaneous full-duplex calls can a 50-channel cell handle?

    A. 25.
    B. 50.
    C. 100.
    D. Unlimited.

56. How many competing cellular companies can operate in the same area?

    A. One.
    B. Two.
    C. Four.
    D. Unlimited.

57. Which of the following frequency ranges is used by the cellular telephone service?

    A. 88–108 MHz.
    B. 152–153 MHz.
    C. 454–464 MHz.
    D. 824–894 MHz.

58. Which of the following frequency bands is used for unlicensed and broadband PCS operation?

    A. 901–902 MHz.
    B. 930–931 MHz.
    C. 940–941 MHz
    D. 1850–1990 MHz.

FINAL EXAMINATION ANSWERS

1. A — The **talk battery** is not a part of the single-line telephone set.

2. B — **Dial pulses** do not originate from the central office.

3. C — **Facilities** is not a correct classification for a telephone set.

4. C — The **ring** (**negative** supply voltage) is the **red** wire.

5. A — The telset operating range for DC current is from 20 to 120 milliamps. Therefore, at **10 volts, 10 milliamps** the telephone set will not operate properly.

6. B — **Supervisory signals** provide data on calls for billing telco's customers.

7. D — With the telset **off-hook, closed hookswitch**, direct current flows through the telephone set.

8. D —The **E & M** signal is not heard by the caller or called parties.

9. B — **3600 Hz** is out-of-band, since it is not within the 300 Hz to 3000 Hz bandpass.

10. B — In the ten-digit number (202) 425-7033, **425** accesses the central office for a specific zone.

11. A — **10,000** subscribers that can be handled by a single central office using four digits (0000 to 9999).

12. A — The approximate ratio of time savings achieved by the DTMF system is **10:1**.

13. C — **852 and 1427 Hz** are not used for DTMF dialing.

14. D —**770 Hz and 1336 Hz** are generated by a DTMF 5.

15. C — The **talk battery** is not initiated by the loop relay.

16. B — The approximate resistance/impedance values for the basic telset and its circuits are **200 ohms DC, 600 ohms at 1 kHz, 6 kilohms ringer**.

17. B — **50 Hz** is within the limits of a basic telset's ringing signal.

18. A — **350 Hz and 440 Hz** correspond to the central office dial tone signal.

19. D — A 2/4-wire converter most likely to be found **between a CO and a 4-wire toll switch**.

20. D — The **Class five** switch is designated for use in the central office.

21. A — **Red, green, black, and yellow** insulation colors are used in 4-conductor station wire.

22. B — The frequency of the ringer signal applied to the single-line telset is **20 Hz**.

23. C — The ringer signal originates from the CO at **90 volts**.

24. B — **1000 ohms** is a practical value of loop resistance found in CO circuits connected to single-line telsets.

25. B — An **LC oscillator** circuit is more likely to produce a sine-wave signal.

26. C — A **multivibrator** circuit is more likely to produce a square-wave signal.

27. C — A **sawtooth wave** is the typical output from a simple RC relaxation oscillator.

28. D — The **frequency** of DTMF signals is the most critical to detect.

29. C — **Current** is detected by the loop relay.

30. D — If two signals of identical frequency are applied to the phase detector, the detector's output voltage will be **zero**.

31. B — A **digital NOR gate** is driven by the dual DTMF tone decoders to detect the frequency pairs for each of the dial digits.

32. D — A **comparator** is often used to accurately detect voltage levels in communication systems.

33. D — A **comparator** is used within the IC timer to obtain precise switching times from a charging capacitor.

34. C — **0.5 mile of 22 gauge** wire has the highest resistance.

35. C — **23 gauge** is the smallest wire diameter that can be used for a 10-mile loop to provide at least 20 mA DC from a 48-volt current source, when the DC telset resistance is 200 ohms.

36. D — **26 gauge spaced at 0.080-inch on-center** will have the greatest inductance.

37. A — **16 gauge spaced at 0.220-inch on-center** will have the greatest capacitance.

38. D — A signal generator has a source impedance of 600 ohms. A **900-ohm** load impedance will provide for the highest power transfer from source-to-load.

39. D — **16 gauge spaced at 0.220-inch on-center** will have the greatest attenuation of higher-frequency signals.

40. A — **26 gauge spaced at 0.080-inch on-center** will have the highest characteristic impedance.

41. A — **26 gauge spaced at 0.080-inch on-center** will have the greatest phase distortion of higher-frequency signals.

42. C — Coaxial cables are most immune to interference from when placed adjacent to other cables or wires.

43. C — The transmission line has electrical properties equivalent to a network of **series R, series L, and shunt C**.

44. D — An **electronic amplifier** is used to compensate for the frequency response and power losses of transmission lines.

45. B — A loading coil is placed in a transmission line to cancel the effects of the line's **capacitance**.

46. B — The **R and L** electrical properties of a transmission line change in proportion to frequency, due to skin effect.

47. A — D-conditioning applies to **S/N and harmonic distortion**.

48. C — **1 kHz, 0 dBm, and 600 ohms** are telco's standard frequency, power, and impedance reference levels for terminal equipment.

49. B — With an amplifier input specified for –10 dBm TLP, and a measured input signal of +4 dBmO, the power level of the signal is **–6 dBm**. ($Signal_{dBm}$ = TLP + dBm0)

50. D — Noise power is specified as +40 dBrnC. Since the noise reference is –90 dBm, the power level is **–50 dBm**. ($Noise_{dBm}$ = rn + dBrnC)

51. A — **Station cards** process the control signals between key telsets and the CPU.

52. D — A **KSU** is not present in a PBX system.

53. C — In the telephone inductry, POTS is an acronym for **plain old telephone system**.

51. C — **832** pairs of channels are assigned for cellular use.

52. A — A 50-channel cell can handle **25** simultaneous full-duplex calls.

53. B — There can be **two** competing cellular companies operating in the same area.

54. D — The frequency range **824–894** is used by the cellular telephone service.

58. D — The frequency band **1850–1990 MHz** is used for unlicensed and broadband PCS operation.